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PREFATORY NOTE.

By the Director.

Since the issue of the last series of scientific papers from the Marine Biological Station of Canada, (under the title 'Contributions to Canadian Biology, 1901') researches of a varied and important nature have been continued by the staff of scientific investigators who, from season to season, have worked at the station. It is pleasing for me to be able to report that many of the ablest Canadian biologists, as well as University assistants, demonstrators, and students qualified to conduct original researches, have taken advantage of the facilities provided by the Dominion government; and the investigations, begun in 1899 at St. Andrews, New Brunswick, have been continued at Canso, N.S. (1901-1902), Malpeque, P.E.I. (1903-1904), and Gaspé, P.Q. (1905). The stay in each locality has been limited to two years, and biennially the station has been towed upon its scow to a new site, thus permitting of the fisheries in an extensive series of areas coming, in succession, under the purview of the scientific staff. Indeed, during the comparatively short career of the institution up to the present date, all the maritime provinces have been visited, and vital fishery questions in each have been looked into, and important facts ascertained. In each locality where the station has been placed the fish and fisheries characteristic of the district adjacent, have occupied the attention of the staff, but faunistic, botanical, chemical and other studies have been carried on assiduously. A thorough understanding of the conditions essential to the prosperity of any fishing industry is only possible when the various biological and physical features of the coast and the waters concerned have been ascertained. The study of the 'environment' of fish and fisheries is as necessary as the study of the fish themselves and their habits, or of the practical methods of exploiting fishery resources. Hence the completion of exhaustive reports upon fisheries in all their aspects, practical, commercial and scientific, is possibly only after continued work for many years. Hasty publication often implies immature results, and doubtful conclusions and recommendations.

A glance at the table of contents will show that the thirteen reports, now presented as 'Further Contributions,' deal with practical and technical matters bearing upon the fisheries, and the important and complex problems which they involve.

The 'Plankton' investigations of which Professor R. Ramsay Wright furnishes the first instalment, indicate the kind and abundance of food, in the area examined, upon which the schools of young food-fishes subsist. In the absence or scarcity of such food these young fish would perish, and it would, of course, be vain to expect a plenitude of adult fish in future years. The abundance of marketable fish depends upon the abundance of young fry hatched out in the 'nurseries' or breeding areas in the sea, and the young fish can only be plentiful when the minute floating food or 'Plankton' is locally rich, varied, and plenteous. It would be superfluous to dwell upon the great value of such researches as those carried on for some years by Professor A. P. Knight

(Queen's University). The effects of dynamite, illegally used in fishing operations, and the actual and unquestionable results of sawdust pollution in waters frequented by fish, have been investigated with thoroughness and rigid accuracy, for the first time in Canada, under the auspices of the Marine Biological Station. Intense public interest has been aroused by the publication of the preliminary accounts of Professor Knight's prolonged and laborious investigations, and the final reports are included in the present series.

Dr. Joseph Stafford, who for some years has devotedly performed the duties of curator at the station, and year after year, has spent the whole season from the opening to the close, in faunistic, fishery and other studies, especially the study of fish-parasites, contributes further interesting papers, and it is important to note how many of the universities of the Dominion have sent workers to the Marine Biological Station. Toronto and McGill Universities have been prominently represented. Queen's University, Kingston, has almost every season sent some representative of its academic staff, while Dalhousie (Halifax), Mount Allison (Sackville, N.B.), Acadia (Wolfville, N.S.), and other universities, including some United States' institutions have sent workers. The station has been hampered in various ways, by the limited nature of its reference library, but especially by the lack of a suitable fishing launch fitted for investigating deep-sea grounds. These wants are happily being gradually supplied, the library already embraces a valuable and representative series of memoirs and reference works, and with due encouragement the Marine Biological Station of Canada will ere long rank as one of the best and most valuable fishery research institutions on this continent.

EDWARD E. PRINCE,
Dominion Commissioner of Fisheries.

December 30, 1905

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THE PLANKTON OF EASTERN NOVA SCOTIA WATERS.

AN ACCOUNT OF FLOATING ORGANISMS UPON WHICH YOUNG FOOD-FISHES MAINLY SUBSIST.

By R. Ramsay Wright, M.A., LL.D., &c.,

Professor of Biology and Vice-President University of Toronto.

(WITH SEVEN PLATES.)

INTRODUCTION.

Within recent years much attention has been given to the floating microscopic organisms which abound in all great bodies of water—fresh and salt. It had not been sufficiently realized until it was insisted upon by Haeckel, Hensen, Brandt and others, that our attention has hitherto been arrested chiefly by the animal life of the sea and the great lakes to the neglect of the vegetable food-supply which necessarily forms the *conditio sine qua non* for the existence of all animal life. On land the vegetable kingdom everywhere seems to be predominant, and to account amply for all the animal life which feeds on it directly or indirectly. But in the ocean, the obvious plants—the seaweeds, brown, green and red—form a mere inconspicuous fringe of vegetation along the shore, and do not extend out beyond a few fathoms in depth. Such a fringe of vegetation can practically be neglected as the basic food-supply of the animal life of the ocean, and the question comes to be, 'Whence do marine animals derive their fundamental supply of nourishment?' Living creatures are either builders or destroyers of protoplasm, or in familiar parlance, either plants or animals, and the former are necessary to sustain the life of the latter. In what form then do these necessary protoplasm builders exist in the sea and other great bodies of water?

The answer is, in the form of microscopic plants, often quite invisible to the naked eye and yet present in such enormous numbers, not only at the surface but through the whole of the superficial layers of waters, some sixty fathoms deep (as far as the sunlight reaches, on the presence of which their power to build protoplasm depends) that it has been calculated that an acre of sea-water—surface measurement—furnishes as much nutritive vegetable matter as does an acre of rich meadow land in the course of a year.

No one sailing over the Atlantic suspects the presence of such a rich vegetation, and indeed it can only be disclosed by filtering the water through an exceedingly fine fabric—the finest silk gauze used by millers is that generally employed for the purpose —and this is usually done by towing a net of such a fabric behind a boat so as to insure a definite amount of water passing through it.

Investigations made in this way may be either qualitative—merely to determine the nature and relative numbers of the organisms so captured—or quantitative—to determine the absolute amount of the different kinds of organisms in a column of water of given dimensions.

It is such quantitative investigations which have rendered the statements as to the richness of the marine vegetation possible, which are made in the foregoing paragraph.

The tiny organisms obtained in this way are not all plants, many of them are animals, feeding on the former, and themselves serving as food for larger creatures.

Many of our important food-fishes, such as those of the herring and mackerel families, are known as plankton feeders, for their gill-arches are provided with a sifting apparatus which enables them to sift out from the water which they are breathing, the minute organisms it contains, and the young stages of all fish pass through a phase when they are dependent on the same kind of nourishment. Without a glance at the catch of a tow-net it seems incredible that fish of any size should be dependent on such inconspicuous food, but sometimes at the height of the summer a careful inspection of the water itself betrays its richness in life. In our inland lakes, e.g., the 'blossoming' or 'flowering' of the lake in August, when the water is full of minute green points, is a phenomenon which often attracts attention and is only a temporary exaggeration of a permanent condition. The astounding rate at which these minute creatures reproduce themselves, is one of the noteworthy facts about them.

Although there are various methods of reproduction, one of the commonest is that of division into two after they have grown to their typical size. Maupas has calculated that if a little Infusorian, not as big as the head of a pin, continued to reproduce at its ordinary rate of division—five times a day—it would, at the end of a month, form a mass of protoplasm a million times as big as the sun ! It is obvious that the rate of consumption of such creatures by larger forms must be very high to keep down the population to the normal relations in which we find them, and of course the rate of reproduction of the minute plants is dependent on the amount of the carbon, nitrogen, and other elements of their food available in the sea water.

But it must be remembered that these minute plants are constantly being devoured by animals, some little bigger than themselves, others much larger, hence no one species ever gets the opportunity of monopolizing the ocean.

Another noteworthy circumstance is that our northern waters appear to be richer in plankton vegetation than those nearer the equator, richer at least, in the mere quantity of vegetable matter, not in beauty or variety of form, for the tropical species are certainly more varied, and in many cases more beautiful than the northern ones. To this wealth in microscopic organisms of our waters we owe the circumstance that we are able to supply warmer climes with the surplus of our fish production. The reason of this greater richness is not apparent; Brandt has suggested that it may be due to a deficiency of nitrogen in warmer waters owing to the more favourable conditions for the growth of denitrifying bacteria.

Before giving a detailed description of the minute life of the ocean, a few remarks as to its general character will be appropriate. The simple plants which constitute the bulk of the marine vegetation are frequently *Peridinia* (Plate I.), single cells of odd shape usually furnished with a decorated shell, and swimming actively by means of two long lash-like 'flagella.' Some of these *Peridinia* it is improper to describe as plants, for they seem to be destitute of chlorophyll and therefore obliged to depend upon preformed living matter for their food.

Another group abundantly represented in the open water is that of the *Diatoms* (Plate II.). These have always a resistant siliceous shell, and do not swim actively like the foregoing. Both of these groups of plants, however, require to live in the stratum of water penetrated by sunlight, and they do this either by their own exertions, but usually owing to the presence of organs which render floating easy, such as long delicate spines or the like, or again, to the presence of fat or oil which diminishes the specific gravity of the cells.

The chlorophyll in the *Peridinia* and *Diatoms* is often masked by other colouring matters usually of a brownish hue, but there are also unicellular plants of a pure green chlorophyll like some of those represented in Plate III., while in addition to these there occur many extremely minute forms of various colours, but in shape approaching that of the *Chrysomonad,* Fig 11, so small as to elude the meshes of the fabric generally employed. The mesh of the latter is usually 1/200 of an inch on the side, but many little creatures actively swimming by means of lash-like prolongations of their

protoplasm, the so-called '*Flagellata*,' do not exceed 1/3000 of an inch in diameter, and slip through such a mesh with ease, unless accidentally arrested by the threads.

As to the one-celled animals which, of course, feed on these smaller plants, they belong to the various groups represented on Plate IV., and some of them form with *Peridinia* and *Diatoms,* a conspicuous part of the food of oysters and similar molluscs.

Again, the plankton contains many young phases of higher animals which swim about for the earlier part of their life and afterwards settle down to more or less sedentary habits. Such is the case with the sea-urchins, worms, molluscs, &c., some of the young of which are represented on Plate V. These larvæ are, of course, dependent on the minute life of the plankton for their food, and are themselves devoured by larger animals.

But there are also adult animals of small size rarely more than the ⅛ of an inch or so in length, which are constantly eating up the crop of microscopic plants, and which themselves form the bulk of the food of plankton-feeding fish; such are the *Copepods* represented on Plates VI., and the *Tunicates,* on Plate VII. And, finally, reference should be made to the floating eggs of various fishes like the cod, occurring in enormous numbers, few of which ever reach maturity, but are destined to furnish nourishment to the plankton feeders.

Many of the creatures and eggs referred to are exquisitely adapted to their floating (pelagic) life, by their extreme translucency, which makes them almost invisible in the water. Such is notably the case with forms like those shown in Plate V., Fig. 13, and Plate VII., Figs. 11 to 13.

The following account of the organisms observed at Canso is intended as a preliminary one, one of the results of which it is hoped may be the lightening of the initial labours of future investigators into the Canadian plankton, and another, that some workers may thereby be induced to enter this interesting field of research, which requires, owing to the vast extent of our Dominion waters, to be sub-divided to give entirely satisfactory conclusions.

PERIDINIALES.

PROROCENTRIDÆ.

This family embraces the simplest forms of Dinoflagellata, and one of the genera at least suggests by the symmetry of its bivalve shell a relationship to the Diatoms, the colouring of which they also share. The characteristic girdling furrow of the more typical members of the order is absent.

EXUVIAELLA.—*Cienkowsky.*

This differs from Prorocentrum in the lack of the prominent anterior spine of that genus. The specimens observed at Canso, and more frequently at Malpeque, P.E.I., belong to the species *E. marina* (Plate I., fig. 1), but there appears to be a slight difference in that the posterior half of the shell is decorated with some short projecting spines which may entitle it to the varietal name '*hispida*.' The dimensions are $42 \times 33\mu$.

PROROCENTRUM.—*Ehrb.*

P. micans E. (Plate I., fig. 2) also more abundant at Malpeque, appears to be identical with the common European form; it is longer and slenderer than Exuviaella and less symmetrical in outline. The two foregoing species, especially the latter, are important constituents of the oyster's food.

GYMNODINIIDÆ.

PYROCYSTIS.—*Murray.*

This genus was established by Sir John Murray for certain globular cells met with in the tropical and subtropical portions of the ocean, which are frequently responsible for the phosphorescence of the sea. The species met with, *P. noctiluca* (of large size, viz.: 600—800 in transverse diameter) was accompanied by a spindle-shaped form *P. fusiformis* Murray, measuring 1,000 × 160μ. Also at Canso a globular form of smaller dimensions (80 × 150μ) was frequent (Plate I., fig. 3), agreeing admirably in the nature of the protoplasmic contents with *P. noctiluca.* It was also accompanied by a crescentic form (Plate I., fig. 5) 180—250μ in length by 18—25μ greatest width which has been frequently found in the north Atlantic, and described by Schütt as *P. lunula.* The association soon turned out not to be fortuitous, for all stages of segmentation of the protoplasmic contents of the globe into 4, 8, 16, 32 balls were observed (Plate I., fig. 4), which eventually developed into crescents within the shell of the globe before they were freed by the bursting thereof. The curiously curved shapes which they acquire during their imprisonment are explained by their crowded arrangement. A further phase of development, in virtue of which six Gymnodinia (fig. 5, 5a) are formed within the crescent (one of which is distinguished from the others by a red spot), was observed such as is figured by Hensen (No. 1, Plate IV., fig. 30). Schütt figures examples with only a single Gymnodinium in the interior. It seems improbable that only one species of Gymnodinium passes through this remarkable cycle, and further studies may reveal globular and fusiform cystic stages for other species. Another cyst occurring along with the foregoing, but exceeding it in size (diameter 200 — 250μ) is probably related. It was observed frequently with daughter-cells sixteen in number of characteristic form (Plate I., fig. 6) and size (50—56 μ), one alone of which possessed a rosy spot. The cells afterwards undergo encystment when, within each, eight granddaughter cells of similar but smaller size, 12μ, are developed, one only of them retaining the original rosy spot.

In July and August there was frequently observed within dead Copepods or their appendages, a small pink Gymnodinium (Plate I., fig. 7) of subglobular form, 40μ in its longer diameter, generally in an encysted condition, the nuclei recalling the structure figured by Schütt (No. 2, Plate XXII., fig. 73). It is probably a stage in the development of a larger form.

POUCHETIA—*Schütt.*

This genus has been formed by Schütt for the purpose of separating certain chlorophylless species of Gymnodinium which are also distinguished, alone among marine forms, by the possession of more or less complicated organs of vision.

About the midde of July at Canso a form was common which possessed the yellow and brown chlorophyll of Schütt's *Gymnodinium geminatum*, disposed in strands, but in addition a well marked pigment spot with lens of the form represented in Plate I., fig. 8. As this is manifestly of the same character as the stigma of the other species of Pouchetia, that genus must be held to include also chlorophyll-bearing forms. The present species, which on account of its colour may be called *P. ochrea,* was always observed encysted, a single individual or one in various stages of division being inclosed in the cyst. The latter envelopes the body closely, and is not the thick gelatinous investment seen in *G. geminatum.* The undivided cell measures 55 × 45μ but when division is far advanced it gains a length of 100μ. The form and position of the lens and pigment body of the stigma may be gathered from the figure. The latter shows that the two daughter individuals, instead of being in contact by similar surfaces, have their opposite poles adjoining.

GYMNODINIUM.—*Bergh.*

A form (Plate I., fig. 9) was observed on one occasion in July, 1902, which is possibly referable to *G. gracile* Bergh. It is bright pink in colour and measures 125μ in its long diameter. In form it recalls *G. fusus* Schütt.—No. 2, Plate XXV., fig. 81.

PERIDINIIDÆ.

DINOPHYSIS.—*Ehrb.*

This genus is at once recognized by the compression from side to side and the far anterior position of the transverse furrow. Two species are common at Canso and at Malpeque; *D. norvegica* Clap. and Lach. (Plate I., fig. 10), the commonest form, measures 65 μ in its long diameter, and can be distinguished by the coarse reticulation of the shell, the green chromatophores and the curved posterior point.

D. rotundata (Plate I., fig. 11), the next most frequent form, measures little more than 50 μ in length, lacks chromatophores, possesses protoplasm of a very pale pink hue, often much vacuolated, and has a shell decorated with very minute round points. The anterior half of the shell projects considerably beyond the girdle, which is notably not the case in *D. norvegica.* A third species of ovate outline with green chromatophores, but smaller than either of the foregoing (35 — 45μ), resembles *D. ovum,* Schütt, in form, but is not so large.

PYROPHACUS.—*Stein.*

P. horologium Stein (Plate I., fig. 12) is distinguished by the fact that its two valves are subequal and much flattened, so that it presents to the observer one or other of its poles, being then distinguished by the broad transparent flanges overhanging the transverse furrow. The chromatophores are yellowish green. It owes its specific name to the watch-glass shape of its valves. These measure 72μ in diameter. It was common in the middle of July.

PROTOCERATIUM.—*Bergh.*

P. reticulatum Clap. and Lach, is a comparatively small form which no doubt frequently eludes observation. It is marked by the coarse reticulation of the shell (Plate I., fig. 13), which is divided off into angular areas bounded by ridges and provided with a central pore, also by the deep diatom-brown of its chromatophores. It occurred at Canso in July and August, the specimens measuring 46 μ in the longest diameter.

GONYAULAX.—*Stein.*

G. spinifera Clap. and Lach. resembles the foregoing in its colouring, but has a characteristic tubular prolongation of its anterior pole and carries spines on the posterior pole at the sides of the well-marked longitudinal furrow (Plate I., fig 14). The transverse furrow is markedly spiral. The long diameter is 80μ. It was observed in one gathering from Grand river, Malpeque in 1903.

PERIDINIUM.—*Ehrb.*

To this genus there belong several species which are often most abundant in the plankton, and constitute a very important element of the food of those animals which are dependent on such microscopic nourishment. Four species were recognized at Canso, not necessarily occurring at the same time, but frequently overlapping in their maximum periods. Three of these have the angular outline which is characteristic of

most of the species, while the fourth is oval in contour. The three former, however, differ in dimensions and in colour. *P. divergens v. reniforme* Ehrb. (according to Jorgensen, No. 3, p. 36=*P. depressum* Bailey) is the largest (120μ in transverse diameter) and has protoplasm of pinkish hue (Plate I., fig. 15, a. & b.). *P. lenticulare* Ehrb. (Plate I., fig. 16), is greenish, and measures only 80μ across, while *P. pellucidum* fig. 17) is only half as wide, more pyriform, and quite colourless. At the beginning of August, 1902, a variety of *P. divergens* made its appearance, in which the pink colour was more intense, the reniform outline, when observed from one of the poles (fig. 15 c.) more marked, and the vertical height from pole to pole less. *P. ovatum* (Pouchet) Schütt (fig. 18) shares the pink hue of *P. divergens,* but is oval in outline except for the short tube of the apical pole. Its transverse diameter is 75μ and its vertical 55μ. The ventral fissure is bounded by two sharp teeth.

Diplosalis lenticula Bergh, was observed along with the foregoing, with which it may easily be confused on account of its oval outline, but it differs from it in possessing only five pre-equatorial plates instead of seven, and in the fact that the transverse furrow has a strictly equatorial and not slightly spiral course. Its dimensions are rather smaller.

CERATIUM.—*Schrank.*

This genus, like Peridinium, furnishes a very large part of the floating food-material of the ocean. It differs from it in having the tendency to develop flotation organs either in the form of three horns (one apical, two antapical), or by the acquisition of an exceedingly long and slender form like some of the plankton diatoms. The plates of the apical pole are fewer in number, there being only three pre-equatorial plates.

The commonest species at Canso is the widely-distributed *C. tripos* Nitsch, and the variety of this very variable species which is most abundant is *C. tripos macroceras* (*forma intermedia*) of Jorgensen. It will be seen that my sketches (fig. 19) resemble his figure (No. 3, Plate I., fig. 10) very closely. Another form in which the horns are much longer in proportion to the width of the body was commoner, earlier in the year, and is perhaps the form '*scoticum*' of Schütt, while isolated examples of a form with the antapical horns very slightly curved towards the apical pole approach the variety '*arcticum.*'

C. fusus (fig. 20) seems less variable than the foregoing. The right antapical horn is more or less suppressed, and the whole cell attains a length of over 1 mm.

GYMNASTER.—*Schütt.*

One or two examples of the singular little form *G. pentasterias* Ehrb. (fig. 21 a. & b.) were met with in July. The body is oval, 44μ in long diameter, and is distinguished by the presence of two intracellular skeletal plates of resistant siliceous material. After boiling with nitric acid the delicate form of these plates (No. 2, fig. 216) becomes more evident. This form is frequently regarded as one of the Silicoflagellata (p. 9).

DIATOMACEÆ.

Of this group a very large number of marine forms are known, some of them admirably adapted as Schütt has pointed out (Pflanzenleben der Hochsee) for a floating life; others on the other hand confined to a littoral life by the absence of such provisions. The adaptation for floating is generally achieved by a reduction in the amount of silica in the valves of the shell, and in addition by the flattening of the whole cell into a disc-like form or its elongation into a more or less needle-like shape. *Coscinodiscus* and *Rhizosolenia* exhibit the two extremes of these modifications, and both genera were frequently represented in the tow-nettings at Canso. Of the

former genus some very large examples are met with; *C. concinnus* e.g. (Plate II., figs. 1 and 2) in which the sculpture of the valves is exceedingly fine. *C. oculus iridis* and *C. centralis* are smaller and have more obvious sculpture which frequently suggests artificial engine-turning (fig. 3). *Actinoptychus undulatus* Ralfs, *Actinocyclus Ralfsii* Smith and *Paralia sulcata* (Ehrb.) Cleve are not uncommon (figs. 4, 21*a* and *b*, 23.

The commonest species of Rhizosolenia was undoubtedly *R. styliformis* Brightwell, in which the adjacent ends of the valves have very characteristic fitting surfaces (Plate II., fig. 6), but *R. setigera* Bright. was also frequently represented, in which the valves terminate in long spines with a peculiar spear-blade-like enlargement towards the middle of their length (figs. 5 and 7).

Still another type of plankton diatom is that which is furnished with delicate bristles which enormously increase the amount of surface in contact with the water without materially adding to the weight. To this type belongs the genus *Chætoceras,* which is not only rich in species but is profusely represented by individuals in the plankton.

CHÆTOCERAS.—*Ehren.*

In the following account of this essentially planktonic genus, I shall follow the excellent paper of Gran (No. 4), which unfortunately I had not at my disposal when I made the sketches of the forms observed at Canso.

The genus is not only one of the most characteristic, but one of the most abundant of plankton diatoms. It embraces a number of species, the synonymy of which is much confused. I shall only attempt to enumerate those of the diagnosis of which I feel certain. As Gran remarks, the arrangement of the chromatophores is often of considerable diagnostic value : I have found this so in the sketches where it has been noted.

The various species of Chaetoceras generally form chains of more or fewer individuals. Each individual is a shorter or longer cylinder, more or less flattened, the shell bounding which is formed of two valves with an intermediate hoop. The faces of the valves where they come in contact with adjoining individuals are provided with two bristles or setæ, which interlock with the adjoining bristles and diverge from the surface of the chain at an angle generally characteristic for the species. The more littoral species form spores which are peculiar in shape and decoration for the various species, but no such spores were observed during the summer at Canso.

Gran recognizes two subgenera Phaeoceras, in which the brownish chromatophores penetrate into the setæ (which are frequently spinous), and Hyalochaete, in which the setæ are hyaline.

To the former group belongs *C. boreale* Bail. (figs. 9 and 10), the cross section of the cell of which is nearly cylindrical ($24 \times 22{\cdot}5\mu$), and the setæ, which are over 5 mm. long and spinous, are situated in the sagittal plane. The foramina, gaps in the chain between the individual cells, are hexagonal in outline. This form was common at Canso during July and August.

Of the species belonging to the second group, I shall first refer to *C. decipiens* (Plate II., fig. 8) which attracts attention on account of its considerable width which I have measured up to 75μ. The terminal bristles of the chain are shorter and stouter, bear transverse striæ, and are directed nearly parallel to the chain. It was the commonest species observed at Canso. Less common members of the same group were *C. didymum* Ehrb., *C. laciniosum* Schütt and *C. diadema* Ehrb. The first may be recognized by the lyrate foramina caused by a protuberance on the surface of the concave valves as well as by the position of the two chromatophores which fit up against these. In the second (fig. 1), the terminal setæ are wider in the middle and decorated with interrupted spiral lines of thickening. The third species betrays itself, when seen from the valve-surface, by the circumstance that of the four setæ two are in a sagittal plane and two in opposite directions of the transverse axis.

BACTERIASTRUM.—*Schadb.*

This genus is also exquisitely adapted for its floating life. It is composed of cylindrical joints like Chætoceras, but instead of each cell having only four bristles, sixteen may be observed in an end view projecting from the interval between contiguous cells and bifurcating as they radiate outwards (fig. 13). The species, *B. varians,* was observed towards the middle of September, the joints measuring 50 × 25μ, the basal part of the bristles 25μ, and the forks 60μ.

SKELETONEMA.—*Grev.*

This is another similar form, which, however, appears to depend on the slenderness of its cylinders and the tenuity of its siliceous coat for its floating power. The species observed, which is also recorded from the North Sea, is *S. costatum* (fig. 14), portions of the slender cylinders being ribbed. The frustules in the specimens observed measured about 40μ in length by 4 in width.

In addition to the foregoing plankton diatoms, many other of more littoral habit were frequently taken in the tow-nets. Especially is this true of certain forms like *Nitschia closterium* (fig. 18), or *N. longissima* (fig. 19) whose shape favours flotation, or like Striatella (fig. 15), whose siliceous shells are thin, and specific gravity therefore small, or like Licmophora (fig. 16*a* and b) which are frequently found attached to floating or swimming organisms like Copepoda. But there are again other forms, the shape of whose aggregations adapts them to a floating life; such are *Synedra nitschioides* (fig. 22), *Nitschia paradoxa* (fig. 17), whose cells perform the most remarkable evolutions, Tabellaria (fig. 24), and Rhabdonema (fig. 20).

PROTOCOCOIDEÆ.

TROCHISIA—*Kuetzing.*

This genus includes certain unicellular forms with a thick cell-wall generally ornamented with spines or ridge-like projections.

Tr. Clevei Lemm., or a representative of this species, occurring at the same time which the spines are imbedded (Plate III., fig. 1); it was common towards the end of July. The dimensions (the cell 31μ, spines 10μ) are somewhat different from those recorded by Lemmermann (No. 5), and the ends of the spines have more than two or three points, but these differences do not appear to have more than varietal significance.

Tr. Clevei Lemm., or a representative of this species, ocurring at the same time as the above, agrees on the whole in its dimensions (cell 72 — 93μ, spines 98 — 51μ), with Lemmermann's account, but the conformation of the spines is slightly different. There is no gelatinous envelope, the cell-wall is thin and the hyaline spines are often 'flaming' or divided at the end, and may vary in length and strength (Plate III., fig. 2).

Tr. dictyon (Joerg.) Lemm.—I find a single example of this species, the cell-wall of which is marked off by ledge-like ridges into quadrangular or pentangular areas, recorded in my sketches in September, 1901 (fig. 4). The cell measures 96μ in transverse diameter.

HEXASTERIAS.—*Cleve.*

Several examples of the type species of this genus *H. problematica* Cleve (Plate III., fig. 5), occurred towards the end of August, both in 1901 and 1902. It is characterized by 6 (or 7) arms projecting from a central disc about 40μ in diameter. The arms end in sharp recurved teeth. The contents become brown with chloride of zinc, but neither the arms nor the disc show a cellulose reaction. This form has hitherto

been recorded from the North Sea, Iceland, and the neighbouring parts of the north Atlantic.

Another form was observed in August, 1902, which appears to be allied to the above, and which may provisionally be referred to the same genus. One surface of the central disc in this instance is vaulted, and each of the six projections is divided into three tapering curved spines, the middle one of each group being curved inwardly towards the flatter of the two surfaces of the disc. In the specimen observed the disc measured 68μ, the spines 40. For convenience the species may be called *H. spinatrifida* (Plate III., fig. 6.)

I was inclined to refer to the same group an organism which was met with once in an oyster's stomach at Malpeque (Plate III., fig. 4), and which is evidently identical with Hensen's 'Sternenhaarstatoblast' (*l.c.* Taf. IV., figs. 23 and 24). I notice, however, that Hensen describes ciliation in the interior of his cysts.

HALOSPHÆRA—Schmitz.

This genus occurs in the form of free-swimming globular cysts, within which the contents break up into swarm-spores.

H. viridis Schmitz, first observed at the Naples Zoological Station, is a very familiar and abundant element of the plankton in June and July. The youngest cells have diffused chlorophyll with scattered starch-grains and the nucleus is not visible. Eventually the protoplasm exhibits peripheral divisions. It is segmented into numerous cells, still connected by protoplasmic bridges (Plate III., fig. 7), which soon are broken, the individual cells fashioning themselves into monadiform swarm-spores (fig. 7*a*). The largest cells measured were 360μ in diameter.

SILICOFLAGELLATA.

'Cells without external membranes with one or two flagella, one central nucleus and frequently many yellowish brown chromatophores, living within a shell formed of solid or hollow siliceous rods. Reproduction unknown.'

The above is the diagnosis given by Lemmermann of this singular group of which I have found for the most part only empty shells belonging to the genera Distephanus and Ebria.

DISTEPHANUS—*Stöhr.*

D. speculum (Ehrenb.) Haeckel is met with in a variety which appears to be that named *regularis* by Lemmermann, as the radial spines from the basal hexagon (20 μ in diameter) are equal in length (15μ).

EBRIA—*Borgert.*

Ebria tripartita (Schum.) Lemmermann (Pl. III., fig. 9) was not uncommon in August. The genus differs from Distephanus in having a solid skeleton and two flagella. It has hitherto been recorded from the Baltic and the Gulf of Naples. The shells (which measure 20μ in diameter) or fragments thereof, frequently occur in the stomachs of oysters at Malpeque.

FORAMINIFERA.

Comparatively few forms were observed in the plankton, and some of these were undoubtedly young examples of bottom forms swept up by storms. Only once in September did a thoroughly planktonic form make its appearance, viz., a young Globigerina (æquilateralis ?) 150μ in diameter with short delicate spines.

Examples of a Pulvinulina and a Discorbina (Pl. IV., figs. 1 and 2) were less uncommon, the former indeed very frequent in July and August, while a few examples of a Spirillina (fig. 3) were observed in the latter month. A re-examination of these after a study of the benthonic forms would render a closer diagnosis possible.

RADIOLARIA.

Very few members of this class were observed at Canso. Jorgensen records some sixty species off the west coast of Norway, but only three of these were found at Canso. It appears that they are commoner in the open ocean. Of those found, two belong to Hæckel's group of the Acantharia and one to the Nassellaria.

Acanthonia echinoides (Clap. and Lach.) Hæckel (Pl. IV., fig. 4) was abundant in August in both of the years spent at Canso. So abundant, that when sporulating it could be seen in the form of distinct pink dots in the plankton.

The second and much rarer Acantharian is *Acanthostaurus pallidus* (Pl. IV., fig. 5) while the Nassellarian, only observed on two or three occasions, is the *Plagiacantha arachnoides* Clap. (fig. 6). ..

INFUSORIA CILIATA.

This class is represented in the plankton chiefly by the family of the Tintinnidæ, a group exquisitely adapted for pelagic life. It belongs to the order Heterotricha, suborder, Oligotrichidea, in which the ciliary covering is reduced to a few specialized tracts, that round the mouth being the most important. A genus, Strombidium, belonging to another family, Halteridæ, is, however, met with under the same circumstances, and shares the peculiar adoral series of membranellæ.

Strombidium sulcatum (C. and L.) was described from salt water at Bergen, but was observed to be very frequent at Canso in August, 1901. Its outline is somewhat oval, but the posterior end is provided with certain characteristic furrows and the anterior with a projecting beak broader at its extremity than at its origin. The observed dimensions were: 440 × 266μ.

TINTINNIDAE.

In discussing this interesting group of characteristic plankton Infusoria, I shall follow the account given by Jorgensen in his recent discussion of the Norwegian forms. (No. 6.)

I have reproduced in Plate IV., fig. 7, the representation of the characteristic ciliation of this group given by Lang in his Text-book (Protozoa, fig. 53).

TINTINNUS—*Schrank.*

This is characterized by the tubular case being open posteriorly. *T. acuminatus* Clap. and Lach. (fig. 8) was seen only on one occasion, but it is readily recognized by the ridges which occur on the posterior third of the case. The specimen observed measured 258 × 17μ. T. *obliquus* Clap. et Lach. (fig. 9) was only seen in July, both in 1901 and 1902. Apart from its smaller dimensions (80 — 100 × 14 — 19μ), it may be recognized by the absence of the flaring anterior aperture.

AMPHORELLA—*Daday.*

This, like most of the other genera, has no posterior aperture. The commonest species of this genus, *A. subulata* (Ehrb.) Dad. (fig. 10), is exceedingly abundant in the plankton in July and August. Its case is translucent, is furnished with a long posterior spine and is at once recognizable by the series of denticulated rings which

adorn its anterior end and seem to indicate additions to the length of the tube. It appears to constitute a considerable element of the food of the oyster in Malpeque bay.

TINTINNOPSIS—*Stein.*

This differs from the foregoing in having the case beset with foreign material. Two of the species commonly occurring at Canso were easy of diagnosis, viz.: *T. campanula* (Ehrb.) Dad. and *T. beroidea* Stein (figs. 12 and 13). The dimensions of the average examples were in the former case 150 × 130μ; in the latter 43 × 19μ. But in addition to these, forms similar in their general shape to *A. subulata* were very common. T. *davido*w Daday has a total length of 95μ of which 65μ belongs to the spine; it is 40μ wide. The specimen figured (Plate IV., fig. 14) exhibits lines of growth and a fine punctulation of the case, where unconcealed by the foreign material. Another variety measures 45μ in width and 240μ in total length, of which 95μ belong to the spine, which is set on obliquely to the case. No rings were observed in this variety, and the punctulation was confined to the spine (Plate IV., fig. 15). *T. cylindrica* is distinguished by the peculiar form of the aboral end of the case, which lacks the spine of the above, but has a short handle-like process of irregular outline covered with foreign matter.

T. lobiancoi (fig. 16), a cylindrical form, test-tube like in shape, (190 x 45μ) may possibly be a variant of Jorgensen's *T. subacuta,* but no annulations were observed.

CODONELLA.—*Haeckel.*

C. ventricosus (Plate IV., fig. 11) was not uncommon in July. Its form, small dimensions (60 × 42μ) and constricted neck sufficiently distinguish it.

C. lagenula Clap. and Lach.—Common in Malpeque bay, is similar in form, but has no foreign particles adhering to the shell.

PTYCHOCYLIS.—*Brandt.*

P. urnula (Clap. et Lach.) Brandt is a small form very easily recognized by its hyaline case, which is provided with two annular swellings and a thinner slightly inverted and toothed lip (Plate IV., fig. 19). The example observed approached Jorgensen's var. *minor,* in its dimensions (96 × 75μ).

CYTTAROCYLIS—*Fol.*

This genus is characterized by a wall formed of two lamellæ united by transverse plates. The most abundant form at Canso was *C. denticulata* (Ehrb.) Fol var. *gigantea*, Brandt (Plate IV., fig. 18), the tubes of which with their delicate reticular sculpture and toothed orifice were very abundant in the plankton in June and July. The average dimensions of the Canso examples were 470 × 70μ, but shorter and stouter specimens occurred, approaching the variety *typica,* in which the length is only three times the breadth. The sculpture ceases as the case narrows to its delicate terminal spine, which is as a rule sharp, but occasionally terminates in a knob.

ECHINODERM LARVÆ.

Three of these were observed, viz., (1) The Pluteus of *Strongylocentrotus dröbachiensis* in its second stage. In addition to the two pairs of ciliated epaulettes at the base of the post-oral and posterior dorsal processes, there is a posterior ring. The greatest length of the larva, which occurred in the end of June and the beginning of July, is 1.25 mm. (Plate V., fig. 1). At a later date (2) an Ophiopluteus made its

appearance on July 11 (fig. 2), and a comparison of my sketches with Mortensen's figures (Nordisches Plankton IX., 16) induces me to refer it to Ophioglypha, of which *O. robusta ayres* is the common species at Canso. My sketches, however, are not sufficient to give an accurate picture of the form of the skeleton (Plate V., fig. 2). Still later, on July 18, (3) the first Bipinnariæ of *Asterias vulgaris* were recorded (fig. 3).

TREMATODES.

A few examples of what has been supposed to be the pelagic egg of a Trematode were detected in both years; such at least, is the interpretation placed upon these by Canu (Ann. de la Station Aquicol. de Boulogne-sur-mer, Vol. I., pt. 2, p. 112, Plate VII., fig. 8-9). The Canso specimens are longer and comparatively slenderer 290 μ (of which 182 to tail) × 50, while Canu's measure 150 × 42.

The larvæ of *Hemiurus appendiculatus* Rud, and *Derogenes varicus,* O. F. Müller, diagnosed by Dr. Stafford, are found occasionally free, as well as in the interior of Copepods (*Acartia* sp. at Malpeque).

ANNELIDA.

Of the two families which are exquisitely pelagic in their habit, the Alciopidæ and the Tomopteridæ, only the latter was represented in the tow-net takings at Canso, and that by a single example taken out at sea in the end of August. (Plate V., fig. 5). From Apstein's account of the Tomopterids of the Plankton expedition, one would have expected that it would have turned out to be *T. helgolandica* or *T. septentrionalis,* but his excellent account enables me to diagnose it as a young example of *T. Mariana.* It measured 1.25 mm. in length, had the cephalic tenacles the two pair of tentacular cirri and five pair of parapodia developed, of which the two first carried yellow (phosphorescent ?) 'rosettes' on the basal joint, while the middle line of the back had some twelve distinct pink spots, which were also present on the tentacular cirri of the parapodia. No rosette was observed on the fin of the third pair of parapodia.

LARVAL FORMS.

Before any satisfactory account can be given of these, it will be necessary to work over the adult Annelids of the region. Two Spionid larvæ, one of them *Polydora ciliata,* were very common, but I propose to confine myself here to registering the occurrence of some forms of particular interest. The Polygordius larva (Plate V., fig. 6) was frequent in July, as was also a Mitraria larva (fig. 7), but my attention was more arrested by a larva developing within an egg-membrane of peculiar character, of the systematic position of which I have not been able to satisfy myself. The embryo in question was first observed towards the end of July in an early stage of segmentation, with a large space between it and the peculiar shell of some 225 μ in diameter. On the inner surface of the latter were to be seen numerous pear-shaped vesicles apparently opening to the exterior (fig. 8). Towards th end of the month a single cilated band had been established and later a well-marked anterior bunch of cilia as well as a posterior ring (fig. 9).

Still later two bunches of provisional setæ, some 130 μ in length, five in each bunch made their appearance (fig. 10), two brown eye-spots became obvious, and two caudal (sensory ?) organs were observed. The shell lost the peculiar pear-shaped vesicles as development advanced; it was perforated by the cilia and bristles, and eventually was ruptured by the escape of the larva. This I observed towards the middle of September, but only detected a single example of such a free larva.

Another developing embryo of larger size, 555 μ, related to the above, was also observed less frequently in September. The shell lacked the vesicular structures observed

in the other case, but had a peculiar superficial sculpture and certain oval depressions (fig. 11) not related to the two ciliary rings whose cilia projected through the shell in separate tufts. Several of the oval areas were counted in front of the prostomial ring.

Since the above was written Leschke's paper* on the pelagic Polychæte larvæ of the Bay of Kiel has appeared, in which he records having met on one occasion with a larva similar to the former of these. He also cites previous records of similar occurrences which had escaped me, and from which I am able to state that the Canso larvæ obviously belong to the genus Nerine.

POLYZOA.

The only larval Polyzoan met with was the Cyphonautes larva of *Membranipora sp.* (fig. 12), which was abundant in June and July.

CRUSTACEA.

CLADOCERA.

Two genera were represented abundantly at Canso, viz.: Podon and Evadne. Of the former there were two species appearing at the end of July and of August respectively. I have not been able from my sketches to determine these with certainty, as the diagnostic features given by Timm and Hansen (the number of bristles on the exopodites of the various legs) are not recorded there. I suspect the earlier species, however, to be *P. polyphemoides* Leuckart, on account of its shorter tail lancets and smaller size, and the latter to be *P. intermedius* Lilljeborg. I find my sketches record that the caudal lancets of the larger species (Plate VI., fig. 1) are tinged with violet and toothed, also that the sculpture of the surface of the shell is different in the two species (figs. 1 and 2).

The two species of Evadne, however, are obviously *E. Nordmanni* Loven, and *E. spinifera* P. E. Müller, the former characterized by the greater elongation of the shell and the latter by the spine which it carries (fig. 3). The former species was abundant at the end of June, the latter common at the end of August. The first winter egg was observed in it on September 6.

OSTRACODA.

Only two species of this order were observed, neither belonging to the genus Conchoecia, so it is possible that the few examples observed are fresh water forms swept into the plankton.

COPEPODA.

Comparatively few of the numerous species of this interesting order occurring have been definitely diagnosed. The commonest forms are, however, recorded here.

SUBORDER GYMNOPLEA.

CALANIDAE.

Of this family the largest representative, a very abundant one in the earlier part of the summer, was *Calanus finmarchicus* Gunner. It attracts attention by its

*Leschke, Beiträge zur Kenntniss der pelagischen Polychaetenlarven der Kieler Föhrde. Wissenschaftl: Meeresuntersuchungen: VII.-123. Cunningham and Ramage, Trans. Roy. Soc., Edin., XXXIII. Claparede & Metschnikoff Z. W. Z. XIX, p. 329. Krohn & Schneider Müller's Archiv, 1867, p. 498.

large size and by its transparent pale pink colouration. Fig. 4, Plate VI., is after Giesbrecht's figure of this species, and serves to call attention to the arrangement of the appendages in the order.

Pseudocalanus elongatus Boeck (Plate VI., fig. 5) was exceedingly abundant in July and August, and can be readily recognized by the orange pigment and the green of the vulvar region, as well as by the morphological features described by Giesbrecht. The eggs, about 100μ in diameter, are in a loose cluster, from 7 to 13, and spermatophores of 310μ length were frequently observed with a longer or shorter tube. The individuals frequently carried clusters of a diatom (*Lichmophora*, sp.). As Giesbrecht has noticed, the larva of *H. appendiculatus* (p. 12) is found in this copepod, but it also occurs in *Acartia bifilosa.*

CENTROPAGIDAE.

Both *Centropages hamatus* Lilljeborg (Plate V., fig. 6), and *C. typicus* Lilljeborg were observed, the latter much less abundant and appearing considerably later than the former. They may be readily distinguished by the different armature of the genital segment of the female.

Temora longicornis, O. F. Müller, a northern form, was also abundantly represented.

PONTELLIDAE.

Tortanus.—This generic name has recently been substituted by Giesbrecht for Corynura (preoccupied), and expresses the remarkable distortion of the abdominal region which characterizes the genus. One species of this genus (*T. discaudatus* I. C. Thompson and H. Scott), Plate VI., fig. 9, was exceedingly common at Canso from the end of July to the middle of August. It was first recorded by the authors named from the Gulf of St. Lawrence and afterwards observed by Wheeler at Wood's Hole and described as *Corynura bumpusii.* I have little to add to the excellent account furnished by him except to suggest an explanation for the distortion of the furcal region. The second post-genital segment of the female carries a bunch of stiff hairs adjacent to that on the first, while the second abdominal segment of the male has certain grooves on the chitinized projection formed by the right posterior angle, as well as a few scattered bristles. In the right antenna of the male the first joint distad of the knee (19-21) carries two pectinate ridges, while the 17th and 18th joints have one each (fig. 11).

The explanation for the distortion of the abdominal region of the female (which is also transmitted in a less degree to the male) is furnished, I believe, by the mode of attachment of the spermatophore, which I had occasion to observe very frequently. The spermatophore itself is over 1 mm. long by 125μ wide. It is attached to the genital segment, in the ordinary way by a conical cement piece, but a much larger piece of yellowish cement is plastered on to the large right furca and its spine, and is connected with the beginning of the efferent canal of the spermatophore by a solid cord of cement of the same appearance (fig. 10).

Some cases were noticed in which an attempt had been made to attach a second spermatophore; in such the supplementary supporting patch of cement did not succeed in finding anchorage.

SUBORDER PODOPLEA.

CYCLOPIDÆ.

Oithona plumifera Baird (fig. 8) is one of the commonest forms of this section, and apart from its form can be recognized by the bright-red elongated eye-spot and a certain faint orange tinge in the abdomen. The spermatophores are pyriform, with a short stalk, and measure about 70μ.

HARPACTICIDAE.

Microsetella atlantica Brady and Robertson (fig. 12) was frequently taken in the beginning of July. Ripe females are readily recognized by the long setæ, as long as the body (547 μ), the orange-red colouring which extends to the eggs disposed in a single packet underneath the abdomen, and the denticulation on the segments.

Harpacticus chelifer (fig. 13) is also common.

AMPHIPODA.

The commonest member of this order in the Canso plankton is *Euthemisto compressa* Goes, Plate VI. fig. 14. It was most abundant in June.

DECAPODA.

Throughout the month of July there was plenty of opportunity of observing the various larval phases of Cancer and two species of Pagurus. One of the latter which occurred towards the end of the month differed from the figures I have studied by the presence of sixteen setæ on the telson, and a rostrum which only reached to the middle of the basal joint of the antennulæ.

UNIDENTIFIED EGGS.

Two pelagic eggs are of very frequent occurrence. One of these (Plate VII., figs. 1 and 2) is that of a gastropod and is contained in a horny capsule which suggests in its shape a low wide-brimmed hat, and resembles closely the figures given by Hensen (l.c. Taf. IV., fig. 25-30) of his 'Barbierbecken-statoblast.'

A further resemblance to his figure 25 is that two eggs are frequently found in the cavity of the capsule. The dimensions, however, of these structures do not agree for whereas the whole capsule of Hensen's statoblast merely measures 200 μ, that of the egg in question is 675 — 775 μ, the flat rim measuring 140 — 160 μ or so, the capsule proper some 400 μ; its cavity, (or cavities if there are two eggs) 140 — 150 μ, and the unsegmented egg about 120 μ. Segmentation had begun towards the end of June, the spheres having a certain pinkish hue by reflected light. By the eighth of July the shell and velar cilia could be made out. Larvæ ready to escape were observed up till the middle of August, but were not recognized in the plankton nor referred to the parent mollusc. Fig. 3 is a rough sketch of the shelled larva. I have not found any pelagic gastropod egg-capsules referred to in any of the literature accessible to me.

The second egg-capsule, commoner than the foregoing, I have not been able to localize even as definitely. It has something of the same form (fig. 4), viz., a subglobular capsule of 120 μ in diameter, with a thin rim 100 μ broad, which, however, unlike the former, does not lie entirely in the same plane, but is often much curled. The capsule is yellowish in colour and the rim shows a network of fine fibres (fig. 5). Empty capsules were common, and embryos (fig. 6) were observed in July and August within others, but I did not succeed in diagnosing them. These egg-capsules, when deserted, were frequently occupied by a species of Chytridium.

Among the numerous gastropod veligers found at Canso that of *Aeolis despecta* (fig. 7) was particularly common and attracted attention by its pellucid shell. Larvæ of the following Pteropods were also found, Clione aurantiaca (fig. 8) and two species of Hyalaeaceæ (figs. 9 and 10).

TUNICATA.

Although this Phylum furnishes a very large number of interesting forms belonging to the plankton, the only members of it found at Canso belong to the class *Copelata,* which permanently retain the tail and notochord of the larval Tunicate.

The excellent account by Lohmann of the forms belonging to this class, secured on the Plankton Expedition, renders diagnosis easy of the three forms found at Canso. Two families are recognized by him, one Kowaleskidæ, distinguished by the absence of the endostyle, the other Appendicularidæ, embracing all the remaining genera of the group. It is to the latter family that all the three species under consideration belong. The first of these to appear during the early part of July was *Fritillaria borealis* Lohmann (Plate VII., fig. 11). The length of the trunk of the example figured was 540 μ, of the tail 1 mm. Projecting from the lateral edges of the trunk posteriorly are two processes like those which mark the species *F. pellucida*. No signs of the 'house' of the species were observed.

The two remaining species belong to the genus Oikopleura, distinguished from the foregoing by the plumper form, and by the circumstance that the fin of the tail begins at its attachment, not at some distance therefrom as in Fritillaria. *O. labradoriensis* Lohmann replaced the foregoing during the latter end of July, while *O. dioica* Fol was very abundant in the latter part of August. These can be at once separated by the fact that the former has some 16-18 globular 'subchordal' cells under the notochord in the latter half of the tail, while *O. dioica* (figs. 12, 13) has two stellate cells in the same position. It is the only dioecious species; ripe females with eggs 70 μ in diameter were observed on August 20. Although like other strictly pelagic creatures for the most part transparent, *O. dioica* shows some traces of pigment in its intestinal tract, the œsophagus having a faint pinkish hue, while the rest of the intestinal wall, and especially the large gastric cells of the left compartment of the stomach, are decidedly violet. This species appears to live on a small green Flagellate (8 μ in diameter) which I only observed in its stomach.

NOTE.—Through inadvertence some of the literature has been cited in the text, and some by the numbers which follow:—

No. 1. Hensen.—Ueber die Bestimmung des Planktons.—Berlin, 1887.

No. 2. Schütt.—Die Peridineen der Plankton-Expedition.—Kiel and Leipzig. 1895.

No. 3. Jorgenson.—Protophyten and Protozoen.—Bergens Museums Aarbog, 1899.

No. 4. Gran.—Protophyta. Norwegian North Atlantic Expedition.

No. 5. Lemmermann.—Nordisches Plankton.—2te Lieferung.

No. 6. Jorgenson.—Tintinodeen der Norwegischen West-Küste. Bergens Museums Aarbog, 1899.

EXPLANATION OF PLATES.

PLATE I.

FIG. 1. Exuviaella marina. × 600.
2. Prorocentrum micans. × 600.
3. Pyrocystis lunula, globular stage. × 250.
4. " with contained crescents.
5. Pyrocystis lunula with contained Gymnodinia. × 250.
5a. A single Gymnodinium. × 500.
6. Pyrocystis sp. × 150.
7. Gymnodinium sp. × 400.
8. Pouchetia ochrea. × 400.
9. Gymnodinium gracile. × 250.
10. Dinophysis norvegica. × 450.
11. Dinophysis rotundata. × 450.

12 a and b. Pyrophacus horologium. × 300.
13. Protoceratium reticulatum. × 400.
14. Gonyaulax spinifera. × 400.
15 a and c. Peridinium reniforme. × 200.
16. Peridinium lenticulare. × 300.
17. Peridinium pellucidum. × 300.
18. Peridinium ovatum. × 400.
20. Ceratium fusus. × 100.
21 a and b. Gymnaster asterias. × 600.

PLATE II.

FIG. 1. Coscinodiscus concinnus. × 100.
2. Coscinodiscus from side.
3. Coscinodiscus centralis. × 150.
4. Actinoptychus undulatus. × 250.
5. Rhizosolenia setigera. × 200.
6. Rhizosolenia styliformis. × 200.
7. Rhizosolenia setigera. × 500.
8. Chætoceras decipiens. × 150.
9. Chætoceras boreale. × 350; end-view of chain.
10. Chætoceras boreale. Girdle-view of end of chain.
11.
12. } Chæcoceras dichaeta, side view. × 250.
13. Bacteriastrum varians. × 250.
14. Skeletonema costatum. × 600.
15. Striatella unipunctata. × 350.
16. Licmophora lingbyei. × 350.
17. Nitschia (Bacillaria) paradoxa. × 400.
18. Nitschia closterium. × 300.
19. Nitschia longissima.
20. Rhabdonema sp.
21. Paralia sulcata.
22. Synedra (Thalassiothrix) nitschioides. × 350.
23. Actinocyclus Ralfssi. × 250.
24. Tabellaria sp.

PLATE III.

FIG. 1. Trochisia brachiolata. × 400
2. Trochisia Clevei. × 300
3. Trochisia dictyon. × 300
4. Undetermined organism, similar to Hensen's 'Sternenhaar-statoblast.'
5. Hexasterias problematica. × 450
6. Hexasterias spina-trifida. × 300
7. Halosphæra viridis. × 150
7a. One of the swarmspores.
8. Distephanus speculum. × 1000
9. Ebria tripartita. × 750
10a, b, c and d. Eutreptia sp. growing in old boat at Canso, from side. × 1250, 10*a* from mouth, 10*b* to show pyrenoid, 10*c* development in cyst.
11. Chrysomonad.

PLATE IV.

FIG. 1. Globigerina sp.
2. Discorbina sp.
3. Spirillina sp.
4. Acanthonia echinoides.
5. Acanthostaurus pallidus.
6. Plagiacantha arachnoides.
7. Diagram of ciliation of a Tintinnid after Lang.
8. Tintinnus acuminatus. × 175
9. Tintinnus obliquus. × 350
10. Amphorella subulata.
11. Codonella ventricosa. × 600
12. Tintinnopsis campanula. × 250
13. Tintinnopsis beroidea. × 600
14. Tintinnopsis davidoffi. × 200
15. Tintinnopsis davidoffi var:
16. Tintinnopsis davidoffi var cylindrica.
17. Tintinnopsis lobiancoi.
18. Cyttarocylis denticulata gigantea. × 125
19. Ptychocylis urnula. × 250

PLATE V.

FIG. 1. Pluteus of Strongylocentrotus droebachiensis.
2. Pluteus of Ophioglypha.
3. Bipinnaria of Asterias vulgaris.
4. Canu's Trematode egg ?
5. Tomopteris Mariana.
6. Polygordius larva.
7. Mitraria larva.
8., 9. Annelid larva (Nerine sp.) within egg-membrane.
10. Provisional setæ of larva.
11. Another allied larva.
12. Cyphonautes larva.
13. Sagitta sp.
14. Shell of Pteropod larva ?

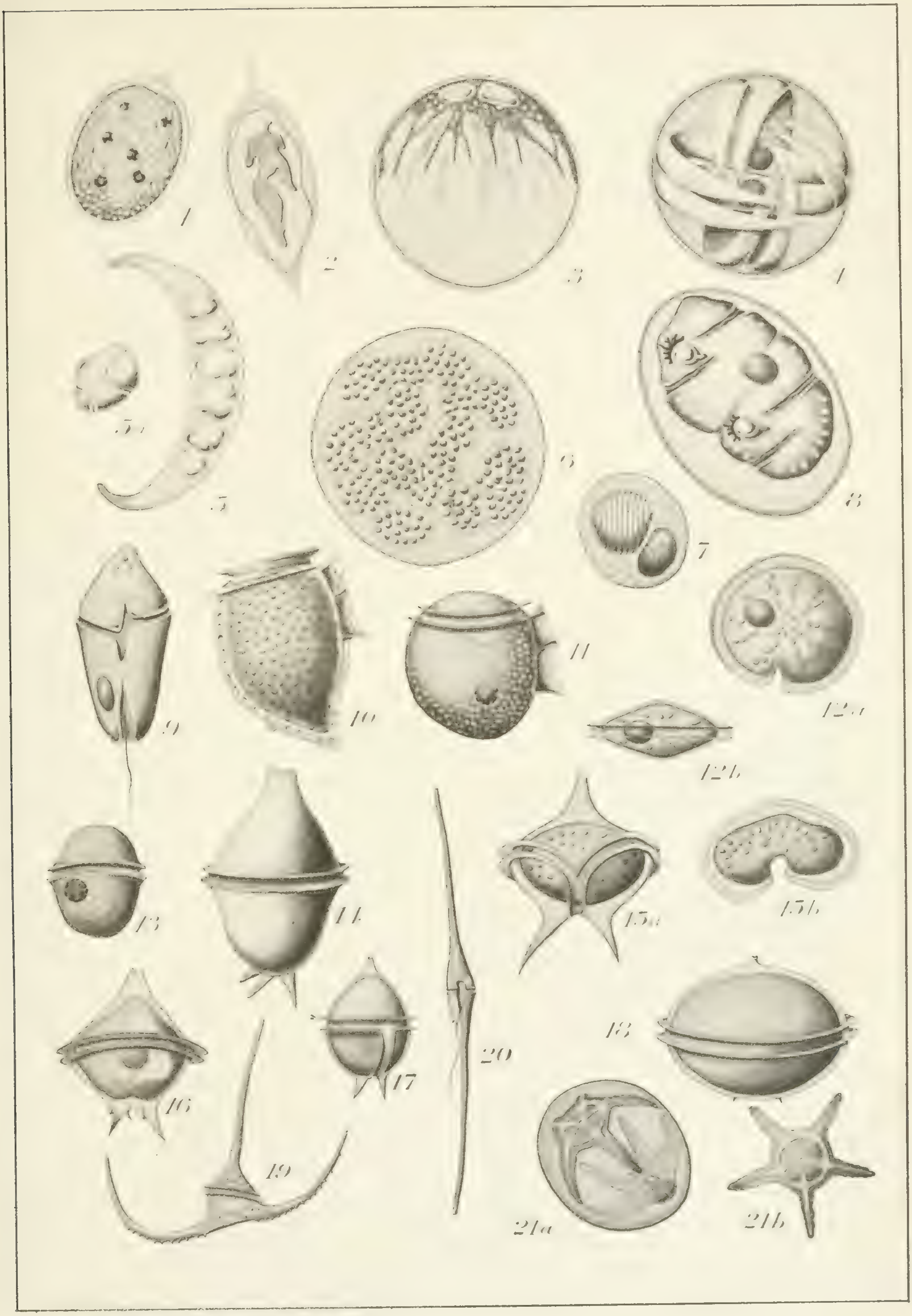
PLATE VI.

FIG. 1. Podon intermedius.
2. Sculpture of shell of P. polyphemoides?
3. Evadne spinifera.
4. Calanus finmarchicus, after Giesbrecht.
5. Pseudocalanus elongatus.
6. Centropages hamatus.
7. Temora longicornis.
8. Oithona plumifera.
9. Tortanus discaudatus.
10. Abdomen of Tortanus fem. with spermatophore attached to furca.
11. Part of grasping antenna of Tortanus.
12. Microsetella atlantica.
13. Harpacticus chelifer.
14. Euthemisto compressa.

PLATE VII.

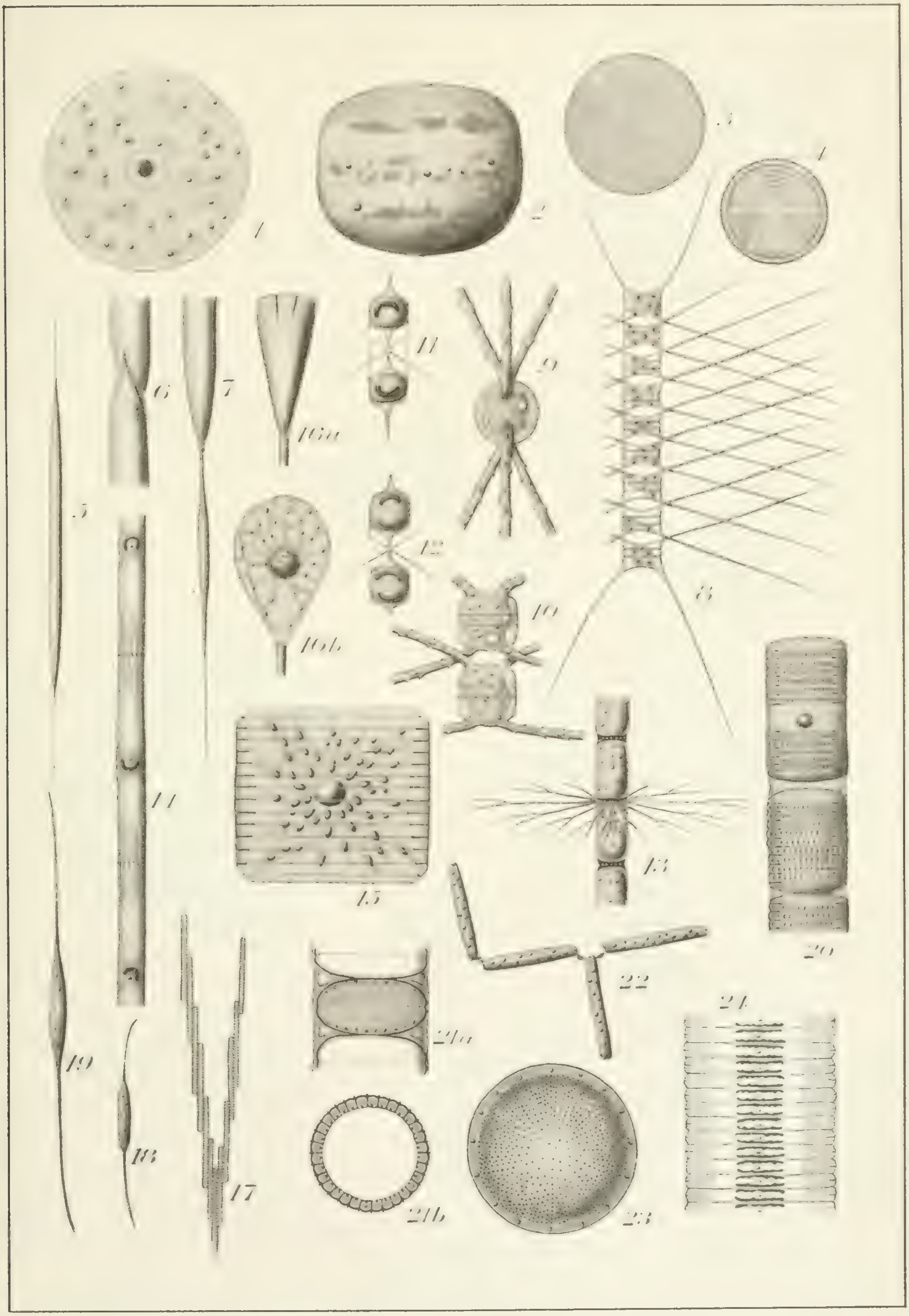
Fig. 1. Undetermined pelagic gastropod egg.
2. Undetermined pelagic gastropod egg.
3. Contained larva with shell.
4. Undetermined pelagic egg.
5. Structure of flange of same.
6. Contained larva.
7. Larva of Eolis despecta.
8. Larva of Clione aurantiaca. × 30.
9.,10. Larval shell of Hyalaeaceæ. × 150.
11. Fritillaria borealis.
12. Oikopleura dioica.
13. Oikopleura dioica, the tail with subchordal cells.

PLATE I



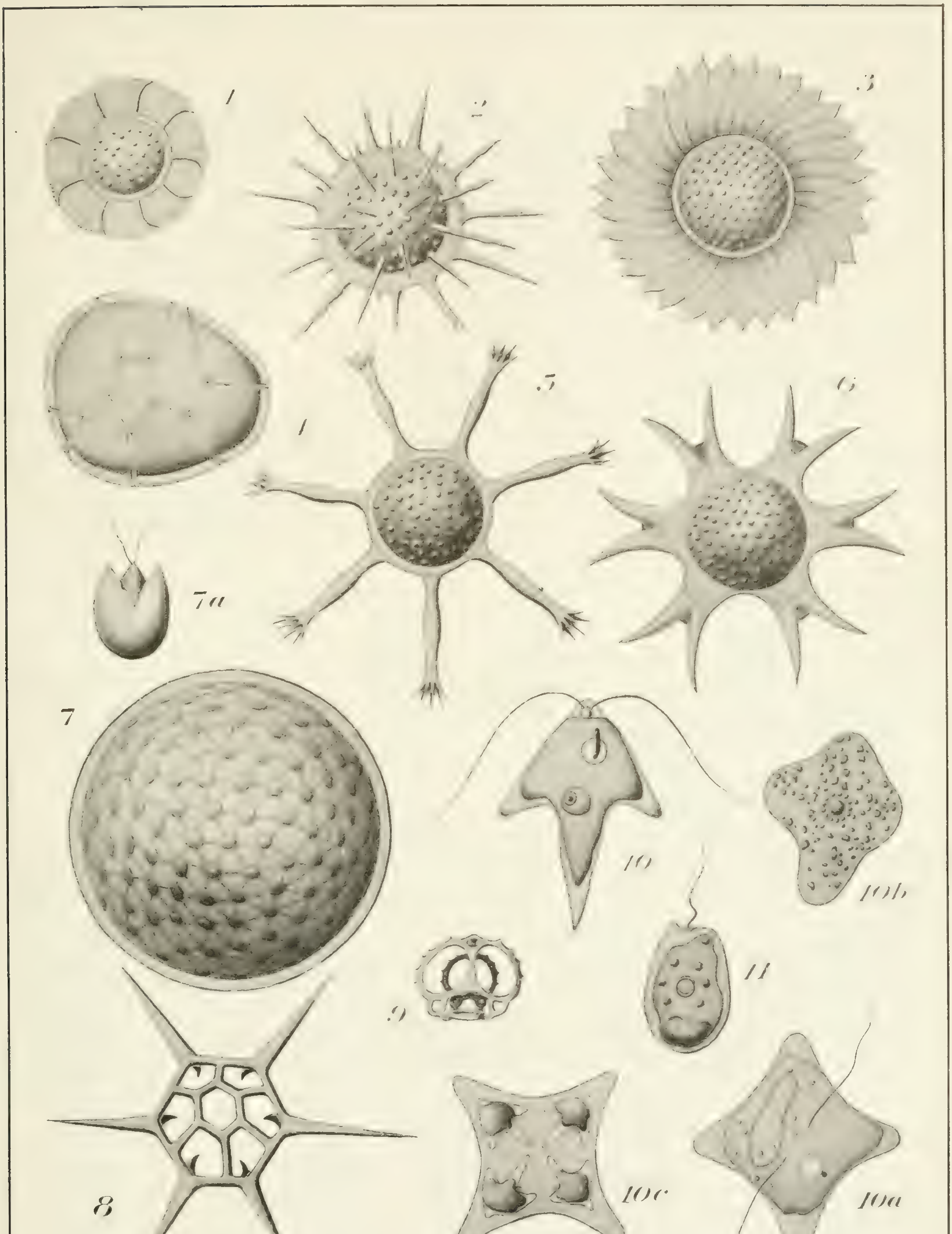
J R G Murray after sketches by R Ramsay Wright

PLATE II



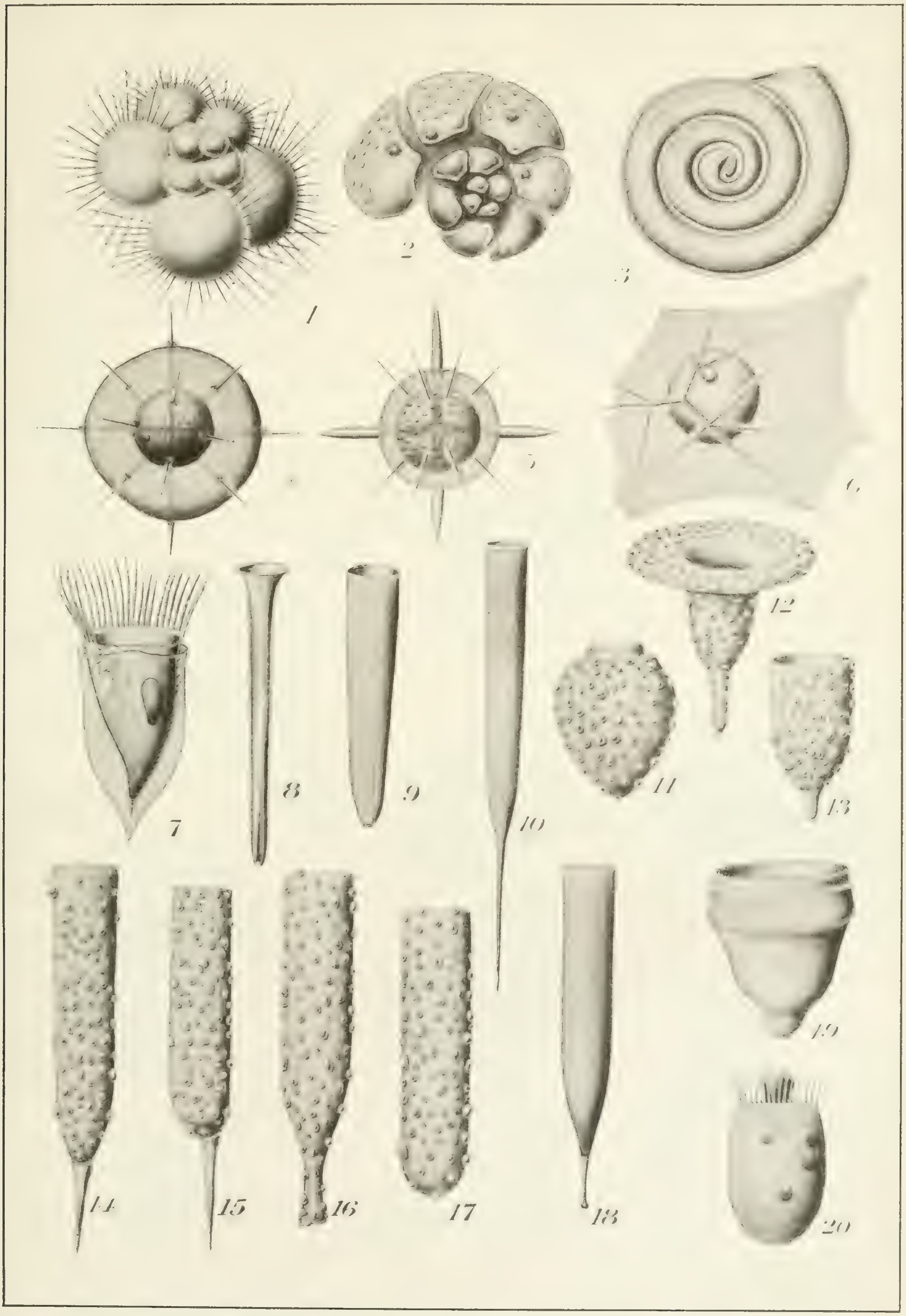
J. R. G Murray after sketches by R. Ramsay Wright

PLATE III.



J. R. G. Murray after sketches by R. Ramsay Wright.

PLATE IV.

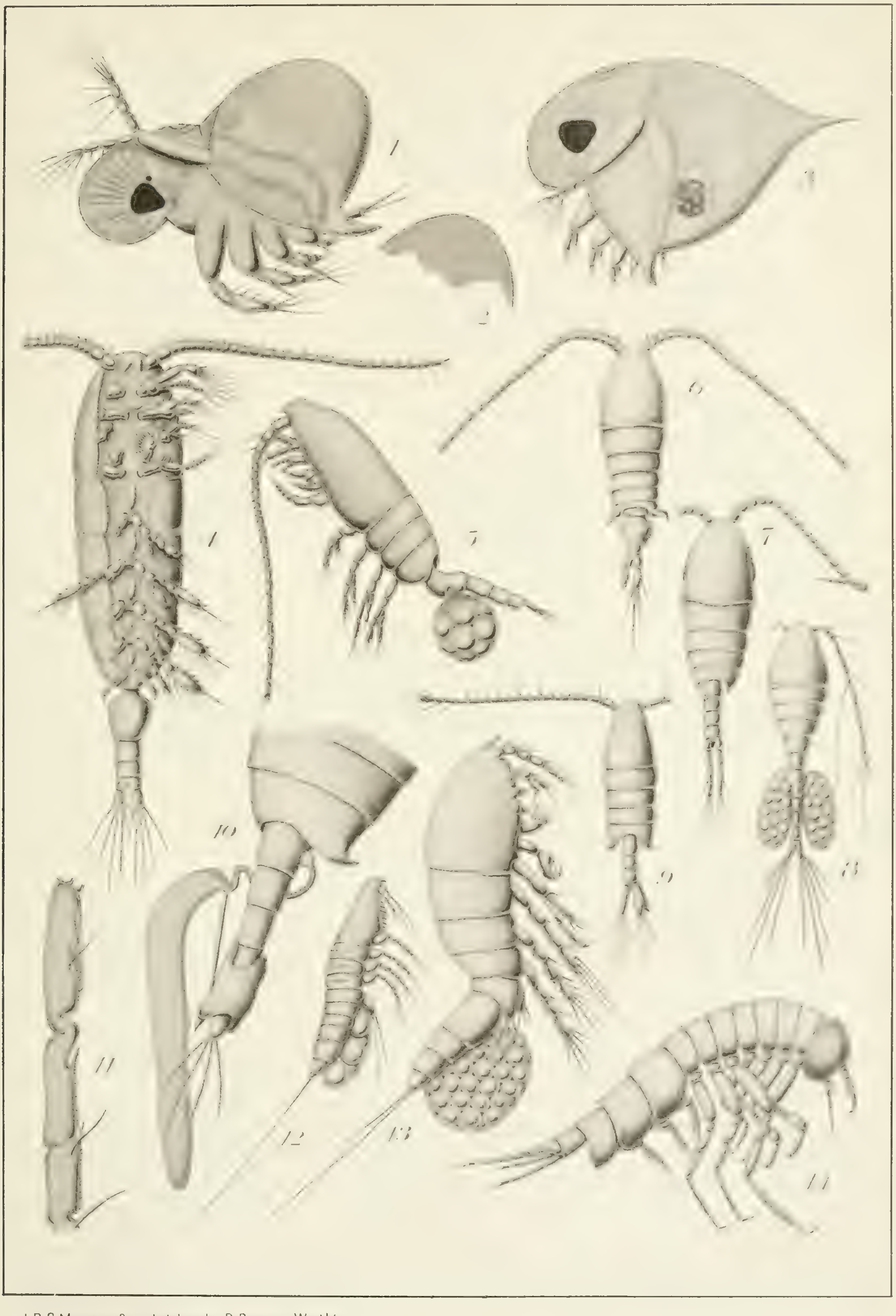


J R G Murray after sketches by R Ramsay Wright

PLATE V.

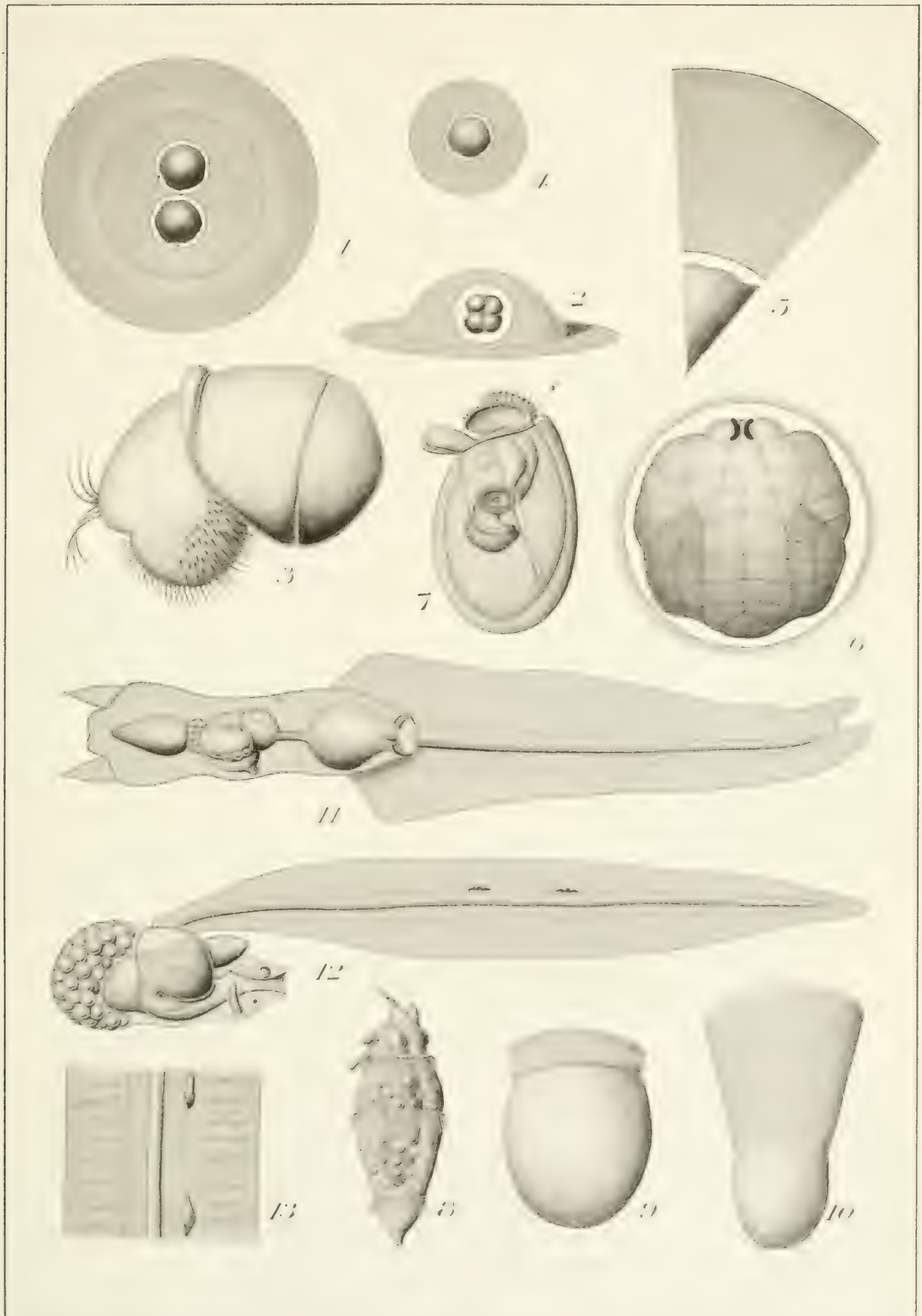
J. R. G. Murray after sketches by R. Ramsay Wright

PLATE VI



J R G Murray after sketches by R Ramsay Wright

PLATE VII



J R G Murray after sketches by R Ramsay Wright

II

THE EFFECTS OF DYNAMITE EXPLOSIONS ON FISH LIFE.

A PRELIMINARY REPORT BY PROFESSOR A. P. KNIGHT, M.A., M.D.,
QUEEN'S UNIVERSITY, KINGSTON, ONT.

In issuing his announcement of the opening of the Dominion Biological Station for the season of 1901, the director, Professor Prince, suggested that some experiments should be undertaken 'on the wastefulness or otherwise of fishing with dynamite.' It was subsequently arranged that this should be my work for the summer, and the requisite permission to use dynamite having been obtained from the Ontario Fishery Department, Toronto, and from the Department of Marine and Fisheries, at Ottawa, experiments were begun the first week of July, 1901.

ACKNOWLEDGEMENTS.

Before beginning this report, I must acknowledge indebtedness to E. Abbot Johnson, Esq., L'Orignal, Ont., for hospitality and assistance, in carrying out experiments on the Ottawa river. Also, to my colleague, Dr. J. C. Connell, for the use of his launch in carrying on the experiments in Kingston harbour, and similar indebtedness to the Messrs. Whitman Bros., for extensive use of the tug 'Vulcan' off Canso harbour. It would have been impossible to carry out this investigation without the assistance given by these gentlemen.

DYNAMITE.

The dynamite used was the variety known as dualin and has the following composition:—

Nitroglycerine	40 parts.
Fine sawdust or wood flour	30 "
Potassium nitrate	20 "

It is usually sold in cylindrical sticks, or cartridges, of two sizes, one being six, the other eight inches long, and about 1¼ inches in diameter. The cartridges are encased in oiled paper, and done up in five pound packages. Each package contains 6 small cartridges, and 14 large ones, and costs about $2; that is, a little over 8 cents per cartridge for the small ones, and about 10 cents for the large. Fuse costs 75 cents per hundred feet, and caps or detonators about 75 cents per hundred.

The dynamite used at Canso was that manufactured by the Acadia Powder Company, Halifax; that used on Lake Ontario was obtained gratis from the Ontario Powder Company, at their head office, Kingston, and Mr. Smith, the general manager, kindly instructed me how to use the explosive, and furnished me with a copy of the pamphlet, which they send out to their customers. The following are extracts from it, so far as they have a bearing upon my work:—

INSTRUCTIONS.

'Dynamite, when properly used, is perfectly safe, but like all compounds of nitro-glycerine, must be handled with care and judgment. Although it will explode, if roasted up to a high temperature, it burns quietly if set fire to. In order to cause the explosion in practical use, therefore, it must be fired by means of an ordinary 'Detonator' with fuse, or by 'Electric Detonators' with a battery.

'For the former, cut off a piece of fuse to a proper length, straight across, shake all the sawdust out of the detonator, and push the fuse into it gently, nearly as far as it will go, and close the edges of the cap down on to the fuse. Then, if to be used under water, cover edges of cap with soap, grease, tar, or a similar substance, to keep charge inside of cap dry.

'Now, with a small punch, like a pointed lead-pencil, make a hole through the paper in the end of a cartridge of dynamite, as deep as the length of the detonator. If cap has been properly fastened to the fuse, the punched-in edges of the paper after cap is inserted will prevent its being pulled out, in lowering into the drill hole.

'CAUTIONS.

'Dynamite freezes at 42° Fahrenheit, and when frozen it is almost impossible to explode by cap, although it is more sensitive to rough handling. In cold weather, therefore, care should be taken to thaw it until it becomes soft. It is dangerous to do this before a fire. The proper method is to thaw the cartridge by means of a 'Thawing Box,' such as we make and sell at cost, or to keep them in a warm room for several hours before using, and to carry them to the work in a sack, wrapped up in a way to prevent chilling before using, as dynamite at the freezing point, is more sensitive to handling than at either a higher or lower temperature.'

All the explosions at the seaside, and half of these at Kingston, were made by means of a fuse and detonator. Some difficulty was at first experienced in producing explosions at depths greater than ten or fifteen fathoms, but by closing the detonators very firmly round the end of the fuse, covering the joint carefully with common soap, and sinking the detonator well into the dynamite, we succeeded in getting explosions in water as deep as 50 fathoms. When these precautions were not taken, the increased pressure at the greater depths forced water into the caps and prevented the fulminate of mercury from exploding. The difficulty in getting explosions along the Ottawa river was due to the fact that the fuse was not water tight.

In water from 18 to 25 feet deep, no sinker were attached to the cartridges; but in 30 to 50 fathoms, stones or old pieces of iron were used to sink the dynamite as quickly as possible.

LAKE ONTARIO EXPERIMENTS.

The first experiments were made in Kingston harbour, in water about 18 feet deep. Two cartridges were used, the detonation striking our boat like a huge sledge hammer. It stirred up a great deal of mud, and discoloured the water to a radius of 6 or 8 feet, gradually widening to 30 or 40 feet. At first we thought that no fish had been killed, but after waiting for about two minutes they began coming to the surface, and inside of 15 or 20 minutes, 130 perch and 1 small black bass had been lifted into the boat. About three dozen more were left floating; all were not dead; some appeared to be only stunned.

Post-mortem examination of a large number of these fish all showed similar effects: great capillary hæmorrhage from branches of the mesenteric arteries, congestion of the liver and spleen, and invariably rupture of the swim bladder. Portions of the intestines were usually forced dorsally into the cavity of the swim bladder, where, of course, there was also much blood. In rare cases, there was rupture of the venous sinuses feeding the auricles.

VARIATIONS IN DESTRUCTIVENESS.

The first explosion and its results were typical of all the work done last summer. Of course the results were not constant, for obvious reasons. The destructiveness of the explosive varied according to easily recognizable conditions. It varied with (*a*) the charge of dynamite used, (*b*) with the depth of the water, (*c*) with the number of fish present in the neighbourhood of the explosion, (*d*) with their distance away, and (*e*) with the kind of fish.

That the destructiveness varies with the weight of dynamite exploded, needs no demonstration. This is probably true of all explosives. Many different charges were used, usually varying from one cartridge up to eight. The larger charges did not always result in bringing up the larger number of fish. The number killed depended more upon the number of fish in the neighbourhood than upon any other condition. For example, a charge of 1½ lbs. exploded in the Kingston harbour, west of Garden Island, did not bring up a solitary fish, while one cartridge of ¼ lb. weight in St. John harbour, New Brunswick, killed over 800 fish.

The depth of the water was another important condition affecting the destructiveness of dynamite. Explosions were effected at depths varying from 1½ to 300 feet. It produced little, if any, destruction of fish life at shallow depths, say, less than 10 to 12 feet. The reason of this probably is, that at slight depths, the pressure resulting from the explosion is not sufficiently great to rupture the swim bladder. One blast at 18 inches under the surface, sent up a column of water about 100 feet high; another blast about 3 feet below the surface sent up a narrow column about 60 or 70 feet high. In neither case were fish killed, though some must have been present. At 10 or 12 feet below the surface, the explosion lifted a broad cone or mound of water 6 or 8 feet high. At increasing depths, the surface disturbance became less and less marked, until at 45 fathoms or thereabouts, the only evidence of the explosion, after the noise and the tremendous blow on the bottom of the boat, was the appearance of a vast number of small bubbles of gas covering a diameter of from 40 to 60 feet. There was no upheaval of water. Evidently the large volume of gas generated at these depths is, on its way towards the surface, broken up into a large number of distinct bubbles, which separate as they ascend.

As regards explosions at increasing depths, a few of our results may be tabulated as follows:—

No. Expt.	Wt. of Dynamite. Lb.	Depth of Water, in feet.	Depth of Cartridge, in feet.	No. of Fish Killed.
1	⅛	12	12	0
2	1½	14	12	0
3	½	10	10	0
4	¼	26	18	300
5	¼	25	18	160
6	⅜	24	18	35

It is difficult to say whether in Nos. 1, 2, and 3 there were no fish present, or the pressure was insufficient to kill them. The probable explanation of the difference between the number killed in No. 4, as compared with those in No. 5, is that many more fish were present in the vicinity in the former case than in the latter.

No. 6 illustrates another variation in the effects of a dynamite explosion. In this instance not a single fish came up where the explosion occurred. About 30 yards away, seven or eight sunfish were killed outright—not a movement in one of them when picked up. A few moments later, a batch of perch and a few rock bass were seen coming to the surface about 60 yards away. Clearly, therefore, the number of fish killed varies directly with the number present, and varies also with their distance away from the site of the explosion.

Lastly the number killed depends upon the kinds of fish. Those with a thin, delicate texture of the swim bladder are more easily killed than fish possessing a thick,

tough membrane. Pollock were very easily killed for this reason; cunner, very difficult.

Stated mathematically, the energy of the exploding dynamite varies directly with the amount exploded, and diminishes with the distance away, according to an undetermined law, which probably depends upon the relative position of the exploding charge to the bounding water surfaces, upon the nature of the bottom, and possibly also upon conformation. So far as fish are concerned its effects upon them were found to vary (*a*) with the numbers near the site of explosion, (*b*) apparently with their depth beneath the surface, and (*c*) with the strength of their tissues, especially the walls of the swim bladder, and the sensitiveness of the nervous system, though this last was difficult to demonstrate.

CAUSE OF DEATH.

As already indicated, the immediate cause of death is rupture of the swim bladder, and internal haemorrhage. The rupture is evidently due to pressure. When an explosion occurs, there is a sudden liberation of gas tending to produce compression of the water at the site of the explosion The wave of compression travels outwards in all directions—upwards, downwards and sideways. The direction of least resistance is, of course, always towards the surface of the water—hence the upheaval which follows an explosion. Quite frequently we found three other marked injuries, especially in large fish like pollock. Often in these the liver was compressed into fragments, the ribs were detached from the vertebrae along the whole length, and the flesh (temporal muscle) over the skull, after the skin had been cut, could be raised from the surface of the bone, leaving it as smooth and clean as a piece of polished ivory. Here again, the cause of the dislocation of these structures was pressure. The fish is veritably flattened between the compression wave of the explosion on the one side, and the unyielding water on the other; the ribs are torn from their attachments, the liver crushed to pieces and forced backwards into the extra-peritoneal cavity, and the flesh raised clean off the flat bones of the head. The surgeon sometimes meets with a similar experience in accidents due to crushing.

No external marks or injuries were visible on any of the fish, in either fresh or salt water.

SINKING FISH.

Very early in the investigation it became evident that besides those fish which came to the surface and floated, a number were merely stunned, and subsequently escaped, or were killed outright and sank to the bottom. This was important. The destructiveness of dynamite took on a wider aspect than that of merely counting the slain. The wounded and missing had, if possible, to be accounted for. If one could put off a blast in a large pond, count those killed at the surface, drain the pond dry, and then count the living and dead lying on the bottom, the investigation could soon be closed; but this was not the way in which the problem was presented. Accordingly other methods of investigation had to be planned. A simple method, and one likely to throw some light upon these points, was to use the water telescope. This was done in some of the narrow channels off Canso. Cunner abound in the shallow waters along these shores and between the islands, and after some expert knowledge had been gained by using, first a stove pipe and then an old eaves pipe for an aquatic telescope, we put off a blast, and counted our 'spoil.' Twenty-five dead floated belly up: that was one fact, or collection of facts, if you please. Then by the persevering use of our improvised telescope, one observer counted seven, and another of our party counted eleven dead cunner lying on the bottom. We recovered two of these. Port-mortem examination failed to show particularly why they had sunk. There was great visceral congestion, and profuse haemorrhage. In one, the swim bladder was much torn, while in the other, the rupture was so small that no air could be found escaping, except when the whole animal was

placed under water and the swim bladder compressed. The smaller animals generally floated; the larger ones sank.

These results were, however, not satisfactory. In shallow water, explosions always stirred up the mud, and our crude telescope was useless. We determined, therefore, to make a tremendous 'slaughter of the innocents,' and with this end in view selected a small bay, nearly west of Grassy island, and there, set off the largest blast of dynamite which was used during the season—ten cartridges. The noise was loud enough to have awakened the spectral inhabitants of the old French island. There was a tremendous upheaval of water and mud, and in ten minutes wind and tide had spread the dirty water all over the little bay. Twenty-eight dead came to the surface. On returning next morning, we could find only three dead fish lying on the bottom, near where this explosion had occurred; that is, less than ten per cent had sunk in this experiment; in the previous one about thirty per cent.

The next attempt that was made to throw fresh light on this important point was in St. John harbour, New Brunswick. As a preliminary to the real test, a visit was made to one of the salmon weirs at low water. In one compartment of the weir were found two full-grown salmon, one 'fiddler' (small salmon), and ten or twelve adult gaspereau. The time was noon of August 10th. That evening, of course, there was a full tide, and next morning another, so that there were these two chances for additional fish to join their fellows in the weir. At 8.30 next morning, the weir was visited in company with the two fishermen who owned it, and one cartridge was exploded in the compartment which we had previously examined. The two salmon at once floated to the top, also six or eight gaspereau. But the deadly effect of the explosive was brought out in another, and rather unexpected way. Almost simultaneously with the occurrence of the explosion, an immense number of young gaspereau leaped from the water, and then fell back almost motionless upon the surface. They varied in size from $2\frac{1}{2}$ to 5 inches in length. They came partly from inside the weir, but chiefly outside the inclosure, stretching away up towards the city. Evidently a school of these young fish was making its way up into the harbour, or they were leaving it. We counted over 800 of them being driven away by the wind and tide, and estimated that as many of them sank as floated; but this was, of course, mere guess-work.

After rowing along the path of these floating fish for half an hour, we returned to the weir, and awaited the falling of the tide. The tide in this harbour goes out so far that the floors of many of the weirs are left almost dry. We had no difficulty, therefore, in determining the exact number of fish which sank. There they were, 27 gaspereau varying from 7 to 12 inches in length, lying dead on the bottom; 7 others somewhat larger on the average were swimming around in the scanty water remaining in the weir, and in company with these, 2 lively dog-fish which seemed to know perfectly well that they were in a trap. Here were the results which we had been looking for—8 or 10 killed and floating, 27 killed and sunk, and 9 alive. If the dynamite killed the young gaspereau in the same proportions outside the weir, as inside, then 2,500 of them lay dead at the bottom of the harbour in addition to the 800 which we had counted at the surface.

CAUSE OF FLOATING.

Nearly all the fish floated belly up; the sunfish lay more upon their side; lake trout on their back, but with the tail end deep in the water and head above it. Rupture of the swim bladder and escape of its gas ventrally so as to displace the centre of gravity, was probably the cause of the fish floating on their back. But a physiologist can scarcely escape the conviction that the nervous mechanism for the maintenance of equilibrium must have been paralyzed in all of them. Fish which die in water from other causes than concussion, say, from suffocation or from poison, lose their power of maintaining the vertical position, and in these cases they lie on their back because of muscular (i.e., nervous) inability to balance themselves.

WOULD IT PAY.

An attempt was made to see whether a large catch of fish could be obtained in the open sea by means of dynamite. The fishermen at Grand Manan were said to have made it pay during the summer of 1900, and better still in 1901. At any rate, a young seaman whose acquaintance I made through Mr. C. H. Whitman at Canso, claimed to have used dynamite at Grand Manan during June and most of July, 1901. He said that 'whereas only half a dozen vessels had used dynamite in 1900, there were about 90 using it in 1901. It was exceedingly effective with pollock, when they were plentiful and following the red shrimp. They used only one stick of dynamite and exploded it by a detonator and fuse two or three inches long. The men lighted the short fuse with a match or the burning tobacco of their pipes, and then threw the cartridge into the sea from the boat. They judged that the explosion took place about six feet below the surface, but could not say exactly to what depth the cartridge sank before exploding. Hundreds of pollock were killed by one explosion. He was of the opinion that from one-half to one-third of the fish sank and were lost. Other fish were killed besides the pollock. When the shrimps are all eaten up or disappear, the pollock begin feeding upon herring and squid, and consequently separate widely from each other. Under these circumstances, it was not found profitable round Grand Manan to continue the practice—too few being killed to pay for the dynamite and the men's time in collecting the scattered fish. Asked upon what grounds he had formed the opinion that from one-half to one-third sank, he answered that he had come to that conclusion on two grounds: first, by watching the fish sinking after an explosion; and secondly, because on one occasion at Digby inlet he had seen a blast put off beside the wharf in order to kill pollock. After the tide went out they counted as many dead fish on the bottom as they had collected at the surface.'

Such was the substance of the man's story. It remained for us to see how far our experience would confirm his. At the outset, let it be said that although there were six men on board the *Vulcan*, two being experienced fishermen, and all watching eagerly for results, it was generally agreed that it was impossible (by merely watching the surface) to form an opinion as to the number of fish that sank, as compared with the number which floated. We all saw one or two fish sink after some of the explosions, but not one of us from our own observations could confirm the young fisherman's opinion that one-half or one-third sank.

Our experience in St. John harbour compared with his in Digby inlet, showed that three times as many lay dead on the bottom, but they were not pollock.

As regards our experiments in the open sea, the following were typical:—

EXPERIMENT No. 1.

Dynamite, No. of sticks		2
Depth of water, in fathoms		7
Depth of dynamite down in water, fathoms		2
No. of fish killed	pollock	20

One or two fish were observed to sink and not come to the surface again.

EXPERIMENT No. 2.

Dynamite, No. of sticks		4
Depth of water, in fathoms		7
Depth of dynamite down in water, fathoms		2
No. of fish killed	cod	2

EXPERIMENT No. 3.

Dynamite, No. of sticks		2
Depth of water, in fathoms		45
Depth of dynamite down in water, fathoms		3
No. of fish killed	pollock	7

EXPERIMENT No. 4.

Dynamite, No. of sticks		4
Depth of water, in fathoms		45
Depth of dynamite down in water, fathoms		3
No. of fish killed	pollock	1

In experiments 3 and 4 the pollock were schooling all around the boat, evidently chasing squid, which could easily be seen in the water. The eight fish taken in experiments 3 and 4 were all very large specimens. It was hoped that as the explosions took place among considerable numbers of fish, a large 'catch' would be obtained, but such was not the case.

EXPERIMENT No. 5.

Dynamite, No. of sticks		2
Depth of water, in fathoms		30
Depth of dynamite down in water, fathoms		Unknown.
No. of fish killed	pollock	8

In this case the dynamite was simply dropped into the sea, but in most of the experiments it was lowered a fixed distance by line.

EXPERIMENT No. 6.

Dynamite, No. of sticks		2
Depth of water, in fathoms		30
Depth of dynamite down in water, fathoms		30
No. of fish killed		0

The dynamite was attached to a heavy piece of iron and the explosion took place at the bottom. There was no upheaval of water. The bubbles of gas, already alluded to, came to the surface very quietly, and had to be closely watched for, in order to be seen at all. This was characteristic of all the deep explosions.

EXPERIMENT No. 7.

Dynamite, No. of sticks		2
Depth of water, in fathoms		40
Depth of dynamite down in water, fathoms		Unknown.
No. of fish killed	pollock	5

In this experiment it was at first supposed that no fish had been killed; but between fifteen and twenty minutes after the explosion, one fish was picked up; five minutes later a second fish; a few minutes afterwards three more fish. They all exhibited the same peculiarity, viz., that they made repeated and successful attempts to descend into the water, but, within a few seconds they were compelled to come again to the surface.

EXPERIMENT No. 8.

Dynamite, No. of sticks		2
Depth of water, in fathoms		30
Depth of dynamite down in water, fathoms		30
No. of fish killed	pollock	1

This fish came up fifteen or twenty minutes after the explosion.

EXPERIMENT No. 9.

Dynamite, No. of sticks		2
Depth of water, in fathoms		30
Depth of dynamite down in water, fathoms		Unknown.
No. of fish killed	pollock	2

EXPERIMENT No. 10.

Dynamite, No. of sticks	2
Depth of water, in fathoms	30
Depth of dynamite down in water, fathoms	Unknown.
No. of fish killed	0

EXPERIMENT No. 11.

Dynamite, No. of sticks	2
Depth of water, in fathoms	30
Depth of dynamite down in water, fathoms	Unknown.
No. of fish killed	0

In 9 the two pollock came to the surface ten or twelve minutes after the explosion.

Judging from our experience on the *Vulcan*, dynamite fishing cannot be made a commercial success out on the open sea. A few cunner were generally killed, but having no market value, were not counted in our results. We saw no young fish come to the surface during the whole day. Nor could it be said in our experience that pollock were frightened away. After the first day we were out on the bay, we heard that the owners of the small fishing boats were protesting against our operations, as likely to frighten away the fish from their usual haunts. But their fears were groundless, because two days afterwards the pollock were back again in greater numbers than before, and notwithstanding continued experiments on our part, the very best harvest of the season was reaped after our experiments had been concluded. Fishing folk, like other people, often cry before they are hurt.

LOBSTER EXPERIMENTS.

The young seaman already referred to, told a doleful tale of a poor lobster fisherman, who suffered a heavy loss through the explosion of a single stick of dynamite. The fisherman had saved up his catches of lobster by confining them in a pound, in anticipation of a rising market. The pound is a cubical box made of wooden slats, just close enough together to prevent the escape of the lobsters. The box is usually anchored out a short distance from shore, and as the water enters freely through the slats, the lobsters get enough aërated water to live on, if there are not too many of them, and if there is enough of a breeze blowing to create a current in the water. The young seaman's story is that when the lobster fisherman had accumulated about 500 animals in his pound, some mischievous or ignorant person put off a dynamite blast about 150 or 200 yards away, and killed every lobster. As he first told the tale, the lobster pound was 500 yards away, but on cross-examination he was compelled to reduce the distance.

To test the accuracy of this story, six lobsters were obtained from a local fisherman. They were secured on the plea that the biologists required them for scientific purposes. The open season was over, and many of the lobster pots were lying high and dry along the shores, but on sailing out to the sand bar, or to Bass rock, it was easy to see that some of the fishermen were using lobster traps for 'scientific' purposes as well as ourselves.

The first experiment consisted in putting off a blast of 3 large sticks of dynamite at a distance of 80 feet from a trap containing 2 lobsters, and at a distance of 40 feet from a small lobster that was tethered by a piece of twine. The explosion produced no effect whatever upon any of the lobsters.

In the second experiment 2 large sticks of dynamite were exploded at a distance of 20 feet from the small lobster. The animal was uninjured so far as we could see.

The third experiment consisted in setting off two sticks of dynamite within 10 feet of a medium sized lobster. No result.

Finally, 3 sticks were exploded 15 feet away from a trap which contained 5 lobsters. These animals had all been used in the previous experiments. The explosion overturned the trap, nearly overturned one of the piles on which the wharf was built, but it seemed to have no effect upon the lobsters.

We concluded, therefore, that the 500 lobsters of the sailor's yarn had died—not from the effects of a dynamite explosion, but from suffocation. They had been confined in too small a pound for too great a time, and the explosion was co-incident with the fisherman's discovery of their dying condition.

Further experiments are necessary to determine the effects upon lobsters at considerable depths, ours being at 12 to 15 feet.

ON THE OTTAWA RIVER.

Experiments on the Ottawa river were conducted at only one point, viz., about half a mile below L'Orignal village wharf. Twenty years ago, this point was considered a fine spot for pickerel, but to our amazement we obtained nothing but bullheads and suckers. The villagers and inhabitants generally claimed that the government dam at Carillon prevented the fish from coming up the river as they used to do, and that the better kinds of fish were decreasing in number.

EFFECTS ON MINUTE LIFE.

After several explosions in fresh water and one or two at sea, a small tow-net was drawn over the site of the explosions and the material collected was examined under the microscope the next day. Many living organisms such as copepods, phyllopods, &c., were found, and also dead ones, but it was impossible to determine whether the latter were dead when caught, or had died during the night.

Are fish eggs and larvæ killed by dynamite explosions? Because, if they are, this is one of the strongest objections that can be urged against the practice. Here again surface netting failed to show that the percentage of dead eggs or larvæ was increased to any appreciable extent. As is well known pelagic ova and fry both live near the surface of the sea, and it is difficult to understand how these, or any other tiny organisms could be killed by dynamite explosions any more than by the waves of a big storm. Of course, eggs which are laid on the bottom would certainly be destroyed, if they were near the site of any explosion, but further investigation is necessary on these points.

EFFECTS ON THE NERVOUS SYSTEM..

The brains of a dozen fish, half of them killed by dynamite, and half caught by hook and line, were preserved and subsequently examined under the microscope. Leitz

objectives 3 and 6, and ocular 3 being used. On comparison with each other no differences could be observed in their minute structure as a result of their different modes of death. One would expect that there should be differences, but none could be discovered by the methods which were employed.

KILLING OF SEAL.

An interesting result was obtained at St. John, N.B., at the instance of the fishermen. They often lose many salmon, through the depredations of sea-lions or seal. These animals regularly frequent weirs and kill numbers of the imprisoned fish. The fishermen naturally wished to know if seals could be killed by dynamite. Fortunately one of these animals happened to come up the harbour just as our other experiments were concluded. The men rowed out, and a blast of two cartridges was thrown towards the seal just as he dived, forty or fifty feet away. After disappearing under water he must have swam towards the impending explosion. When the tide went out, greatly to the delight of the fishermen, he was found dead sixty or seventy yards away. A deep hollow in the mud marked the site of the blast. Blood was oozing from the eyes, ears and nose of the animal. Evidently he had been killed by fracture of the skull.

CONCLUSIONS.

1. A serious result was clearly brought out in many of the experiments. Large numbers of immature fish were killed. Not one-third of those which came to the surface in fresh water could be sold in the market. Of course, immature fish are killed in other ways. Thousands of young fish perish in weirs all along our coast after every outgoing tide. Fishermen frequently leave them to rot upon the shore. The responsibility for this terrible destruction of immature fish rests in the first place upon the apathy and cupidity of the fishermen, and in the second place upon the Dominion government for allowing the slaughter to continue. Fishermen should be compelled to return immature fish to the sea, because so long as this destruction of young fish is permitted in netting, it is manifestly unfair and inconsistent to prohibit dynamite fishing on the score of its wasteful destruction of immature fish.

2. The second serious objection is the great waste due to the numbers which sink. It would be hardly fair to generalize upon the experiments at Canso and St. John. It is much safer to publish the facts, and the facts are that about one-third of the cunner sink, and that three gaspereau sink for every one that floats. As regards pollock, cod, salmon and other marketable fish, further investigation is necessary if a general conclusion is worth having.

3. Further investigation is necessary also to determine more accurately the effects upon the microscopic life of our inland and marine waters, for such microscopic life is a necessary part of the sustenance of the finny tribes.

KINGSTON, August 9, 1902.

III

ON THE FAUNA OF THE ATLANTIC COAST OF CANADA.

An Introductory Report

BY J. STAFFORD, M.A., PH.D.

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The establishment of a marine biological station for Canada offered an opportunity for a zoological survey of our eastern coast waters. Although the task must be a long and arduous one, yet enough has already been done to indicate some interesting features in the Atlantic marine fauna and to show the advisability of continuing its investigation. Before the establishment of the station, thanks to the enthusiasm of certatin zoologists of Canada and of the United States, there had already been published a number of valuable lists of many classes of animals. But with the advantages of a portable laboratory, moving periodically and by successive stages along our coast, and equipped with the more necessary appliances, facilities have been furnished for a fuller systematic survey than was otherwise possible. The development of a marine laboratory must itself be gradual, and in the initial stages of its growth we can not look for the same thoroughness or comprehensiveness of results as in the later stages to which fall the legacies of a more complete outfit for collecting, and improved apparatus for experimenting, together with a more inclusive library and an experienced staff.

The biological station has been in existence since 1899; the first two seasons were spent at St. Andrews, New Brunswick, and the succeeding two at Canso, Nova Scotia.

In the summer of 1899, several weeks before the carpenters had completed the building at St. Andrews, a small but enthusiastic staff of workers commenced researches there. A row-boat or a hired sail-boat was alone available, and much time was lost in reaching the best grounds, indeed it was often out of all proportion to the real time of collecting; but there was the advantage of a rich faunistic district, offering many facilities for collecting from shore.

In 1900 there was built a 22-foot gasoline launch which gave only a few weeks' service and then had to undergo some change of fittings. A small steamer, the *Annie,* of St. Stephen, was hired for about the same length of time, in which longer trips were made. Altogether the work of the staff at St. Andrews occupied seven weeks of the first year, and fourteen weeks of the second.

In the spring of 1901 the laboratory was mounted on a scow, built at St. John, and was towed around the coast by the Dominion fishery cruiser *Curlew* to Canso N.S.. Here, through the liberality of the Messrs. Whitman, one or more of the staff had the advantage of being frequently taken to the local fishing banks on their steamer *Active,* whose crew also often brought back 'curios' captured by their trawl-hooks. On a few occasions also the same firm kindly gave the use of their tugboat *Vulcan,* and several men, with which to test the 12-foot beam trawl used for experiments.

Upon resuming work at Canso in 1902 the launch was put in order, and, while very useful for short distances, she proved not sufficiently speedy or even safe to venture out to deep water. As the station could not derive much benefit from the *Active,* herself and crew being employed for the greater part of our period of work by the wrecked *Blaamanden,* the staff was so far at a disadvantage. From a consideration of our means of locomotion up to the present, it seems worth while to mention that the first requirement of the station is a vessel large enough and sufficiently seaworthy to carry on work in deeper waters. This has been continually apparent at

Canso, where we could scarcely go any distance from home without being exposed to some danger in the open sea. The coast being bold and rocky yields little to the shore collector and, as a consequence, reliance had to be placed on netting and dredging. But these again we could only perform near shore and for the latter a rocky bottom is unproductive. Rarely has the dredge been used beyond fifty fathoms, and this for two reasons: first, because of our inability to go far out from shore, and second, because of the impossibility of hauling up the dredge by hand from a much greater depth.

Work was conducted at Canso 17 weeks in 1901 and 19 weeks in 1902—in the first of these years for a month before the arrival of the station, in the second, which was the longest term yet spent at the station, from May 1 to September 20. May and part of June were so cold and windy that it was unsafe to venture against the unmanageably rough seas. Hence time was profitably spent in collecting from shore, examining fish brought to the wharfs by steamers and schooners, or working over former collections made at the station.

With these brief references to the areas examined, the time spent in work each season and the means of visiting various localities it is appropriate to mention the methods of collecting. These of course differ according to the nature of the collecting ground and the kinds of animals sought. An excursion along the shore, especially after a storm, yields animals washed up on the beach, some of which, like sponges and jelly-fish, may have been brought long distances. An examination of the sea-weed may prove fruitful in crustacea, snails, worms and the like. With long rubber boots, a pail and a dip-net, one can wade in the water and look for ctenophores, shoals of shrimps and small fish. The turning over of stones between tide marks is most fruitful and reveals numerous species of worms, clams, &c., which may also be procured by digging with a spade into gravelly, sandy, or muddy ground in similar localities. About low-water mark is often to be found a different assemblage of animals, consisting of star-fish, brittle-stars, sea-urchins, sea-cucumbers, &c., and flat stones below the lowest tide-marks may shelter under them sponges, worms, molluscs, echinoderms, tunicates, &c., as well as the eggs and larvæ of many different species. Much can be learned by such procedure, and sometimes one may come upon rare specimens in the most unexpected positions.

With a boat the piles of wharfs, the timbers of piers, the stakes of brush-weirs, the sides of ships below the water-line, may be examined; old lobster pots and such objects, that may have lain for some time in the sea-water, may be hauled up and searched; and the shores of islands reached and investigated. On the way the water is scanned and the dip-net is kept to hand, a large net may be towed behind the boat, or small close-meshed nets may be towed along the surface or weighted to sink to different levels. These catch the small adult forms and larvæ that constitute the food of many fish, and some of the latter may be obtained by hook and line, while others may be secured in shallower water. To procure animals that live on the bottom a dredge, consisting of a quadrangular iron frame with a net attached at one side and a bale at the other, is dragged by a long rope let out behind the boat. The flat jaws of iron scrape off sponges, mollusca, echinoderms, &c., from the rocks which fall into the net behind, or collect shells and stones with hydroids, bryozoa and tunicates attached or mud containing worms and shells. Both the propulsion of the boat and the hauling of the dredge are best performed by machinery, but the smallness of the station's boats prohibits the use of a winch. Generally it has been found more productive to row the boat. Propelled by sail or by the engine the speed is usually sufficient to raise the small dredges off the bottom, but often good catches have been made by simply allowing the boat to drift with the wind or in a surface current. The beam-trawl, already mentioned, consists of a strong beam 12 feet long supported on runners a couple of feet from the ground. Behind is attached a large long-pointed, coarse-meshed net of strong cord. The lower lip of this is strengthened by a rope weighted by small rods of lead, and hangs loosely on the ground into the depressions of which it falls. A rope bale is attached in front, and the whole is dragged by a long rope

after a vessel under considerable headway. This covers a greater area than a dredge, and besides collecting many of the same kinds of animals it also picks up larger objects and captures fish—particulary flat fish.

We have hitherto considered only those animals that are to be found on the surface, or that live deeper in the sea, those that feed on the bottom, that burrow in the ocean-bed, or that creep over rocks or seaweeds. There are others that gnaw their way through and destroy the timbers of wharfs and ships, as well as those that creep over the surfaces of larger animals or fix themselves to definite parts of the skin or gills. One step further, and the collector may find animals that have penetrated into the bodies of others and have even become so completely reconciled to their new homes that they could not possibly continue to live if they were set free.

Live animals taken to the laboratory can usually be kept some time by occasionally changing the sea-water. Better results are reached by supplying the small glass aquaria with sea-weeds, gravel, &c. At Canso two coal-oil pumps were worked at the station so that both salt and fresh water were supplied to the laboratory tanks, and when necessary the aquaria could be thus continually replenished with fresh sea-water. In this way many animals, like sea-anemones, could be induced to expand their tentacles and give an opportunity for their study more conveniently than in their natural habitat.

The first location of the station at St. Andrews presented many special advantages. Its southerly sheltered situation implied, close at hand, a rich and varied fauna, while further out deep-water forms were also obtained, in Passamaquoddy bay and the entrance to the Bay of Fundy. Passamaquoddy bay, screened from the great Bay of Fundy by a chain of islands, is a body of water some 15 miles long by 7 broad. The tide rises and falls about 28 feet, making an enormous difference in the appearance of the shore and exerting a vast influence not only upon the habits of many marine animals, but even extending to the inhabitants of the coast. At many places the falling tide exposes this depth of nearly perpendicular rocks, in the crevices and fissures of which may be found numerous species of invertebrate animals. At other places the shore slants more or less gradually, leaving broad areas of rock, gravel, sand or mud, with animals adapted to every condition. Where the laboratory stood, on the east side of 'the point,' facing Malloch's weir, the lowest tides receded nearly 400 yards. With the rising tide strong currents are swept inwards, between the islands, carrying hosts of marine animals. When the tide falls again numbers of these are left stranded on the beach, or confined in small pools easily accessible to the collector. Approaching the large rivers that empty into the bay one finds other conditions, varying from saline through brackish to fresh water. Turn what way he will, an observer is likely to come upon the common star-fish in many colour-varieties, the sea-urchin and the sea-cucumber, among echinoderms. The mollusca are abundantly represented by the edible mussel, the horse-mussel and the clam, long and round whelks, the purple shell, the periwinkle, and the limpet. Nereis, Arenicola, Nephthys, Rhynchobolus, Lepidonotus, Amphitrite, and Lineus are common representative of the worms; while crabs, hermit crabs, barnacles and sand-hoppers are the commonest types of crustacea. A good many hydroids, polyzoa, and sponges may also be easily procured along shore.

The best collecting places are reached at the period of lowest tides that occur only at the beginning and in the middle of each month. At such times one can wade into the water on the southwest side of the outermost limits of 'the point,' near St. Andrew's, and at arm's depth feel under the projecting ledges or turn over flat stones that are never left uncovered and are not accessible at other periods. This is probably the best place on the coast for sea-peaches (*Cynthia pyriformis*), but many other animals such as Nudibranchs and Sunstars (*Solaster*) occur. In fine sand at about half-tide mark just south of 'the bar' by Malloch's weir, I dug up the only specimens of Balanoglossus and of Edwardsia yet procured at the station. The north side and outer end of this bar are also good collecting places, where the sea-orange (*Psolus Fabricii*) may be picked by hand. The entrance to Katy's Cove

furnishes numerous forms, among which may be mentioned Chirodota, under the mussel beds to the left of the railway bridge; and farther inwards, around the remains of a former dam, are large-sized limpets and tube-worms. Craig's Ledges, on the upper side of the entrance to Chamcook harbour, are resorts rich in sea-anemones, brittle-stars, &c., as are also tide-pools near the outer, rocky end of Pendleton's island. In one of these, small enough to be jumped over and deep as one's waist, supported by a big rock on the side towards the water, and situated at about half-tide mark, during two successive summers, a great collection of animals appeared, comprising many species, among which may be mentioned a brachiopod (*Terebratulina*) which is usually procured only by dredging, and a tube-worm (*Amphitrite*). Near-by in fine sand occurs a species of *Enchytræus*. The 'western block' on the bar between St. Andrew's and the island, and other places, were frequently visited and might be mentioned, but this must suffice.

The dredge was used in the St. Croix river above Dochet Island, between Joe's point and Robbin's Town, off all sides of St. Andrew's Island, up the bay towards the mouths of the Bocabec, Digdequash and Magaguadavic rivers, and once we went as far east as L'Etang and dredged scallops, landing on Frye's island at low water when returning. Opposite where the station stood we dredged at many places round the light-house (Sand Reef Light) and off McMaster's, Pendleton's and Deer islands. We also dredged off Pleasant point, and once went as far south as Eastport, Campobello island, and Lubec Narrows. This last is a rich and interesting region, and it is to be regretted that the staff were unable to examine it thoroughly as well as to visit Grand Manan.

The fisheries of economic importance at St. Andrew's are chiefly cod, haddock, pollock, herring, mackerel, and clams and lobsters.

At Canso the tidal water rises and falls only about 4 feet, affecting but a narrow belt of the shore. There are few accessible rich collecting spots, the coast being generally rocky with here and there small beaches of rounded stones, but seldom gravel, sand or mud. Wherever stones large enough for protection to animals and small enough to be moved by the collector do occur there is intolerably rough water producing friction fatal to delicate animal forms. At such places the stones, worn round and smooth by constant rolling and grinding, are heaped in enormous masses, while at other places they are laid out like pavement stones and solidly cemented into the beach.

At low water mark the star fishes and sea-urchins, which are a feature of the St. Andrew's region do not appear; these, however, may be found in limited numbers under wharfs or at places up the centre of Tickle channel; but sea-cucumbers, that at St. Andrew's may be found clinging to the ledges or arranged by the score in beds below the lowest tide limits, are scarcely ever seen at Canso; only two or three that were brought from deep water were secuerd. Sea anemones flourish under the wharfs and especially at French Point, where large brown, gray, yellow and orange Metridia occur side by side in the fissures of rocks. At this point too the horse-mussel and the edible mussel occur, but the latter may be obtained abundantly at the 'breakwater' (Grave Island). Clams are scarce, but may be found, together with a few razor shells (*Solen*), at Grassy Island and Publicover Beach. The large round whelk may be procured at Indian Cove, and the long whelk, together with the purple shell, the periwinkle, and little limpets, in small numbers at Glasgow Head. Various Nudibranchs live on the sea-weeds under certain wharfs, and fine specimens of *Æolis papillosa* under stones in the narrow channel between Piscatiqui and George Islands. Calcareous sponges, hydroids, and bryozoa occur on the submerged timbers of wharfs or on the sea-weeds to be found there or especially at Cranberry Islands. Arenicola, Nereis, Nephthys and other worms may be dug up from Llanigan Beach, where the laboratory stood, and in Grassy Island Cove and Publicover Beach. The sessile barnacle, the sand shrimp and the crab are the chief crustaceans, but lobsters, so plentiful in deep water among the islands, may be occasionally seen lurking under the edges of rocks along shore.

Dredgings were made at various places in Chedabucto Bay, *e.g.*, at Crow Harbour, on Hydra Shoal, across the entrance to the Gut of Canso, and from that eastward be-

tween Canso and Isle Madame as far as to Green Island. Near Canso, areas were dredged from Tickle Island to the eastward, encircling Derabie Islands and Cranberry Islands, to Cape Canso, and at many places in the harbours and between the islands.

Professor Prince, Professor Ramsay Wright, and others had the opportunity of being on the Mackay-Bennett cable-repairing steamer, and I had the advantage of remaining on board for a couple of days in Dover Bay and saw what animals were brought up on the cables as they were raised.

The most successful places dredged during the two seasons were to the north-east of Tickle Island and Durell Island, and outward from the bell-buoy in a line with the channel entering Canso Harbour from the west. Here occur calcareous and other sponges, a couple of species of sea-orange (*Psolus*), Myriotrochus, Eupyrgus, and one or two commoner Holothurians. Mussel shells dredged at the entrance to Grassy Island Cove have Crepidulas attached.

Although Canso is not a point exceptionally favourable from which to collect inveterbrates in numbers, yet, in one way or another, specimens were procured of most of the species obtained at St. Andrew's, besides a few others. Its proximity to some of the best fishing banks in the world is sufficient proof that there exist somewhere in the adjacent waters vast quantities of smaller animals upon which the fishes feed. The most valuable of these fisheries, as is well known, are the cod, haddock, pollock, mackerel, salmon, halibut, the lobster, and the squid.

As the member of the staff charged largely with the collection of specimens and their storage for purposes of study, &c., a vast amount of the material obtained since the station was founded has passed through my hands. In spite of an inadequate supply of literature necessary for accurate determination of species, I have been able to prepare a list, which when finally revised will be a basis for future work. I shall give here a list of the Porifera, the Cœlenterata with the exception of the smaller hydroids, and the Echinodermata, and propose in further papers to add to the present contribution, after the specimens have been more completely worked over, and others collected from more northerly areas.

PORIFERA.

Ascortis fragilis, Haeckel—St. Andrew's, Canso.
Leucosolenia cancellata, Verrill—St. Andrew's Canso.
Sycon protectum, Lambe—Canso.
Leucandra cyathus, Verrill—Canso.
Amphoriscus Thompsoni, Lambe—Canso.
Polymastia robusta, Bowerbank—St. Andrew's.
Suberites suberea, Johnston—Canso.
Halichondria panicea Johnston—St. Andrew's, Canso.
Reniera aquaeductus, O. Schmidt—Canso.
Eumastia sitiens, O. Schmidt—St. Andrew's.
Chalina oculata (*Pallas*), Bowerbank—St. Andrew's, Canso.
Chalina Sp.—Canso.
Pachychalina, Sp.—St. Andrew's.
Myxilla Behringensis, Lambe—St. Andrew's, Canso.
Desmacidon palmata, Johnston—Canso.
Esperella lingua, Bowerbank—St. Andrew's, Canso.
Esperella modesta, Lambe—Canso.
Plakellia ventilabrum, Johnston—Canso.
——— ——— (on brachiopods)---St. Andrew's, Canso---Sponge, genus and species undetermined.
——— ——— (Tall, rough cylinders, on rocks)---Canso---Sponge, genus and species undetermined.
Halisarca Dujardinii, Johnston—Canso.

COELENTERATA.

Ptychogena lactea, A. Agassiz (medusa)—St. Andrew's.
Tiaropsis diademata, A. Agassiz (medusa)—St. Andrew's.
Tima formosa, L. Agassiz (medusa)—Canso.
Polycanna Grœnlandica, Peron et Lesueur (medusa)—Canso.
Physalia pelagica, Lamarck—Canso.
Cyanea arctica, Peron et Lesueur—St. Andrew's, Canso.
Aurelia flavidula, Peron et Lesueur—St. Andrew's, Canso.
Alcyonium rubiforme, Ehrenberg—Canso.
Alcyonium carneum, L. Agassiz—Canso.
Alcoyonium Sp. (big, lilac-like)—Canso.
Epizoanthus incrustatus, Duben and Koren—Canso.
Edwardsia sipunculoides, Stimpson—St. Andrew's.
Metridium dianthus, Ellis—St. Andrew's, Canso.
Chondractinia nodosa, Fabricius—Canso.
Actinauge Verillii, McMurrich—Canso.
Stomphia carneola, Stimpson—St. Andrew's, Canso.
Actinostola callosa, Verrill—Canso.
Bolocera Tuediæ, Johnston—Canso.
Pleurobrachia rhododactyla, L. Agassiz—St. Andrew's, Canso.
Bolina alata L. Agassiz—St. Andrew's, Canso.
Idyia roseola, L. Agassiz—St. Andrew's, Canso.

ECHINODERMATA.

Cucumaria frondosa, Gunnerus—St. Andrew's, Canso.
Cucumaria calcigera, Stimpson—Canso.
Cucumaria minuta, Fabricius—St. Andrew's, Canso.
Psolus Fabricii, Duben and Koren—St. Andrew's, Canso.
Psolus phantapus, Linnæus—Canso.
Thyonidium productum, Ayers—Canso.
Chirodota ferruginea, Verrill—St. Andrew's.
Myriotrochus Rinkii, Steenstrup—Canso.
Eupyrgus scaber, Lutken—Canso.
Trochostoma ooliticum, Pourtales—Canso.
Asterias vulgaris, Stimpson—St. Andrew's, Canso.
Asterias polaris, Muller & Troschel—Canso.
Solaster endeca, Retzius—St. Andrew's, Canso.
Solaster Syrtensis, Verrill—Canso.
Crossaster papposus, Fabricius—St. Andrew's, Canso.
Ctenodiscus crispatus, Retzius—St. Andrew's, Canso.
Pteraster militaris, Müller—St. Andrew's, Canso.
Cribrella sanguinolenta, Müller—St. Andrew's, Canso.
Ophioglypha Sarsii, Lütken—St. Andrew's, Canso.
Ophioglypha robusta, Ayres—St. Andrew's, Canso.
Ophioglypha nodosa, Lütken—Canso.
Amphipholis elegans, Leach—St. Andrew's, Canso.
Ophiopholis aculeata, Linnæus—St. Andrew's, Canso.
Ophiacantha bidentata, Retzius—St. Andrew's, Canso.
Gorgonocephalus Agassizii, Stimpson—St. Andrew's, Canso.
Strongylocentrotus Drobachiensis, Müller—St. Andrew's, Canso.
Echinarachnius parma, Lamarck—St. Andrew's, Canso.

IV.

A FURTHER REPORT UPON THE EFFECTS OF SAWDUST ON FISH LIFE.

By Professor A. P. Knight, M.A., M.D., &c., Queen's University, Kingston.

The following investigation was begun in the year 1900, at the suggestion of Professor Prince, the fish commissioner for the Dominion of Canada. In the previous year Professor Prince had summarized in a most admirable way the effects of different kinds of pollutions upon fish; and, in order to do this, had consulted a great mass of scientific literature emanating from investigators in both Europe and America. One of the things which struck him as most remarkable was 'the painful lack of scientific demonstrated knowledge as regards the effects of sawdust upon fish life.' The onerous and exacting duties of his office precluded him from undertaking any lengthened series of scientific experiments himself. But from the very start of research work at the Dominion Biological Station he impressed upon the workers the importance of certain fisheries problems which he desired to have solved. Among these was the sawdust question.

Up to 1899, when Professor Prince wrote the report alluded to above, he had ample opportunities, during the course of his official visits to different parts of Canada, of making observations upon sawdust-polluted streams, and as a result of these observations he reached the conclusion that, 'so far as our present knowledge goes, sawdust pollution, if it does not affect the upper waters, the shallow spawning grounds, appears to do little harm to the adult fish in their passage up from the sea. . . . There is no case on record of salmon, or shad, or any other healthy adult fish being found choked with sawdust, or in any way fatally injured by the floating particles.'

The Dominion law was, however, against Professor Prince's views on the matter, and in 1901, the Ontario Fisheries Department proceeded to enforce the Dominion Act. Three mill-owners were fined for passing sawdust and shavings into streams containing protected fish, and many others were warned.

The Deputy Fish Commissioner for Ontario, Mr. S. T. Bastedo, held views the very opposite of these expressed by Professor Prince. In his annual report for 1899, Mr. Bastedo says: 'There can be nothing more destructive of fish life than the depositing of sawdust in the rivers and lakes.'

When two experts hold views so diametrically opposed as those of Professor Prince and Mr. Bastedo, the average member of parliament may well be excused from holding any views at all upon the subject; and yet he is forced to take some stand on the subject of prohibitive legislation? There has been a law against throwing mill refuse into the rivers of Canada ever since 1860. Certain streams were exempted from the operation of that law right down to 1899. The practical question, therefore, now facing the fish commissioners in the various provinces is this: 'Shall the law be enforced?'

Evidently the whole subject should be reported upon by disinterested investigators, and the law should be neither repealed nor enforced until their judgment is received.

The literature of the subject helps us very little. Previously to 1888 there were frequent references to it in the annual reports and bulletins of the United States Fish Commission; but the experts were by no means unanimous in their judgments, as is evident from the following editorial published in *Forest and Stream* in 1899:—

'The effect of sawdust in lakes and streams has been discussed by many writers and with conflicting opinions.

In the second part of the Report of the United States Commissioner of Fish and Fisheries, 1872-73, Mr. James W. Milner gives the result of his observations on the great lakes. Speaking of Green bay, he says that whitefish were formerly taken in abundance in the spawning season in a number of rivers emptying into this bay; but sawmills are numerous at present on all of these streams, and the great amount of sawdust in the rivers has caused the whitefish to leave them. The effect of the sawdust, he states, is to cover up the spawning grounds and destroy the food of the fish. Watson, in the third part of the same report, charges the sawdust with the destruction of the purity and aërated condition of the water, so changing its character as to revolt the cleanly habits of the salmon. He mentions the experience of Mr. Arnold, who had seen the gills of salmon filled with sawdust. Mr. Mather, in Transactions American Fishcultural Association, 1882, and in these columns of the same year, thinks that sawdust is destructive to the young by covering up the spawning grounds, and by polluting the water with turpentine from the pine and tannin from oak.

Mr. J. J. Brown, of Ludington, Mich., in Bulletin V., United States Fish Commission, charges the sawdust and shingle shavings dumped into Lake Michigan with the annihilation of the feeding grounds of fish. The statements of 'Sportsman' and Livington Stone in recent numbers of this paper, are very positive as to the deleterious influence of sawdust in polluting the water, killing the young and promoting the growth of fungus. Mr. Stone believes that after the spawning grounds are covered with sawdust the stream can produce no more trout.

Charles G. Atkins, in Part II., Report of United States Fish Commission, speaks of the Penobscot river. He finds that sawdust has interfered with the success of certain fishing stations, but the salmon are not prevented from ascending to their spawning beds, which are free from obstruction and seem to suffer no injury from the refuse.

Professor H. Rasch, an eminent authority in Norway, communicated his views on the sawdust question to the Norwegian Hunting and Fishing Association in 1873. He admits that rivers on which there is considerable cutting of timber gradually become more and more destitute of salmon, but thinks that the injury is not to the fish directly, but is caused by limiting and partially destroying the spawning grounds. He cites the River Drammen, which was greatly polluted by sawdust for many years, and in which the salmon decreased constantly, until the fishermen at Hellefos begun hatching them artificially and planting the fry annually. Having access to the upper part of the river, which was comparatively free from sawdust, the ascending fish seemed to be little affected by the mill refuse from below Hellefos. His opinion, based upon experience on the Drammen river and the Soli, was that unless the salmon are prevented by impassible dams from ascending above the mill locations, the sawdust will not drive them from the streams nor materially injure them. *Piscator,* Charles Hallock, and Milton D. Peirce have produced statistics and observations to prove that sawdust in streams of Nova Scotia and Massachusetts has not injured the fishing for trout, and has not unfavourably affected any of the river fisheries.

From the foregoing survey it will be evident that there are two sides to the question as to the influence of sawdust in streams and lakes, and it may be possible that some of the states which have legislated against the deposit of this substance in certain waters have placed unnecessary restrictions upon an important industry. Unless spawning grounds are actually covered and feeding grounds destroyed, there would seem to be no case against the sawdust. At all events, the instigators of this legislation should produce evidence of deleterious effects to be remedied by legal enactments, and show that such pollution is necessarily and always fatal, and cannot be mitigated by measures to aid the ascent to the spawning beds.'

Since 1889 the references to sawdust are 'few and far between,' and when its poisonous effects are asserted, the responsibility for the statements is placed upon fishermen or fish dealers. Even the international commissioners of 1893 made no

dogmatic statements of their own, but simply submitted the statements of witnesses whom they had examined.

The experimental part of my work was begun at the Dominion Biological station, St. Andrews, N.B., in 1900, and has been continued since then in the biological laboratory of Queen's University, Kingston, Ontario. The river work consisted of a few weeks' study of the Bonnechere, a tributary of the Ottawa.

Those who are interested in the details of my experimental work are referred to the Transactions of the Canadian Institute, Vol. VII., 1903, under the article 'Sawdust and Fish Life.'

SINKING OF SAWDUST.

Numerous observations were made upon the sinking of sawdust. The general method of experimentation was to add known volumes of sawdust from different kinds of wood to separate vessels containing a measured volume of water. The sawdust was generally dropped quietly upon the top of the water. As a rule, the particles of sawdust began to sink the moment the sawdust touched the water. This was particularly true if the particles were fine; but there were considerable variations in the rapidity with which sinking occurred. So far as could be determined by laboratory experiments, the rate of sinking varied with (*a*) the size of the dust particles, (*b*) the way in which they were made, (*c*) the motion of the water, (*d*) the dryness of the dust, and (*e*) the kind of wood.

Large particles sink more slowly than small ones, because the latter are more easily penetrated by the water.

Large saws which strike logs with great force (as in a sawmill) compress the wood, drive out the air imprisoned in the cells, and produce sawdust that sinks quickly.

Sawdust sinks slowly in perfectly calm water, such as a standing vessel. If the vessel be tapped gently on the side, the sawdust sinks much more quickly.

If thrown into rapidly flowing stream, sawdust is carried downwards until it reaches pools, eddies, or comparatively calm stretches; it then sinks and forms sawdust beds. Some of these are of great extent along the Ottawa river.

Sawdust from different kinds of wood arranged themselves in the following order as regards rate of sinking.—

1. Oak.
2. White pine, 50 to 80 per cent of it in 2 or 3 minutes.
3. Maple.
4. Cedar.
5. Elm.

But it must be remembered that the particles in my experiments differed from each other in size and in the moisture they contained, and consequently different results might easily be obtained by other observers. The important point is that all kinds of sawdust sank in a few minutes in agitated water.

EXTRACTS FROM SAWDUST.

When sawdust was placed in a clean bag, and the bag sunk to the bottom of an aquarium by means of stones, there oozed out of the sawdust a yellowish, brown liquid which lay along the bottom of the vessel. (See fig. 1). In a number of experiments this brownish water occupied 1¾ inches at the bottom of an aquarium containing water to a depth of 16½ inches. The overlying water remained clear and colourless for several days when pine sawdust was used. In the case of cedar, the aqueous extract diffused upwards into the clear water, but never rendered it so dark as that which lay at the bottom. When the brown water was siphoned out, the sawdust soon discoloured more of the clear water. Evidently the water was dissolving out from the

sawdust some soluble material which was stored in the wood. This yellowish brown solution was found to be exceedingly poisonous to fish eggs, fry, living organisms suitable for fish-food and adult fish.

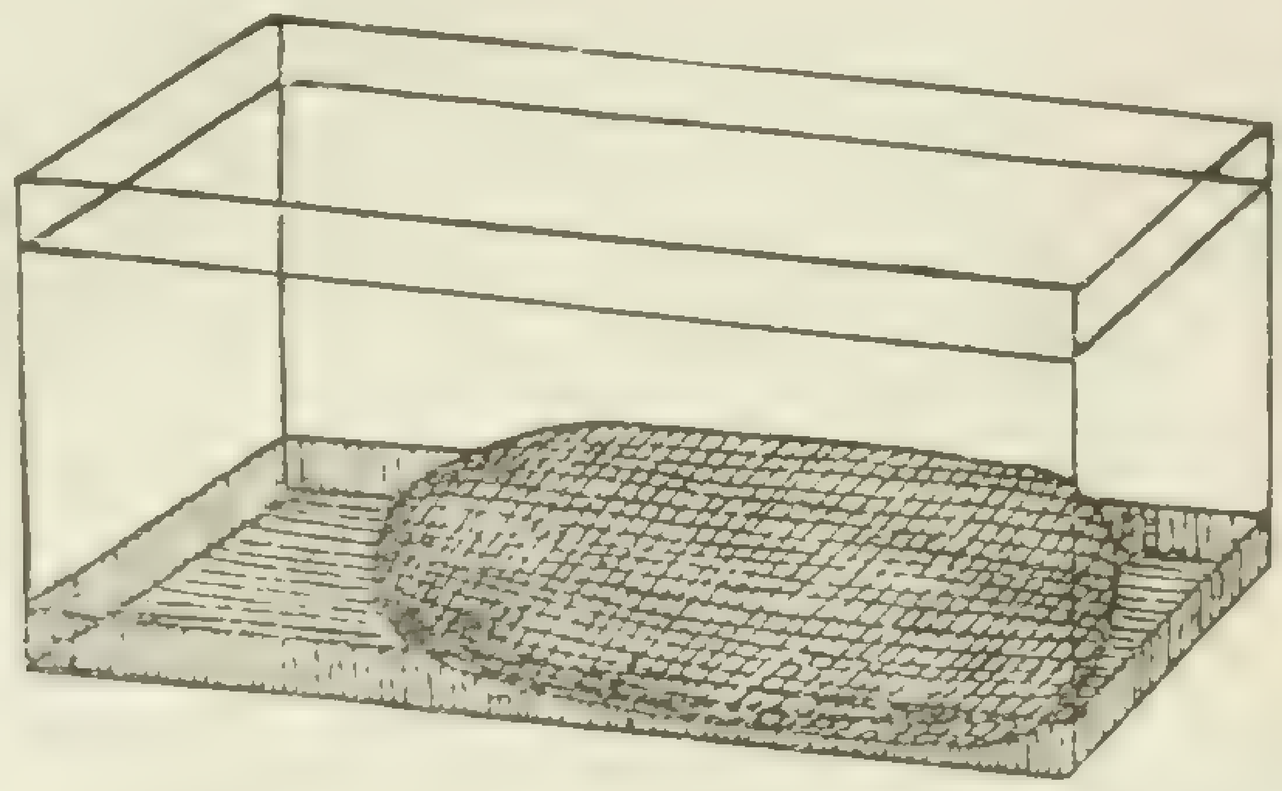

Fig. 1.

SOURCE OF POISON.

In order to understand the source of this poison we must try to get a clear idea of the minute structure of trees. This can be done only by the aid of the microscope. With this instrument, it is easy to see that all parts of young plants are made up of a vast number of very small bladder-like compartments called cells. In older plants and trees, these cells lengthen out and are then called vessels. It is important to note that every cell or vessel consists of two principal parts, (*a*) the outside covering or cell wall, and (*b*) the inside matter or cell contents. If one were to imagine the cells in the comb of a honey bee shrinking into such a small size that each one would be almost invisible, then a very good idea would be obtained of the minute structure of a tree. The wax would correspond to the walls of the cells composing a tree, and the inclosed honey would correspond to the cell contents.

In aquatic plants, like pond silk, the cells are cylindrical and placed end to end, so as to form the long slender threads. In flat leaves, the cells are arranged side by side in two or more layers, so as to form the flat surface; in stems they are packed side by side and end to end. Thus, trunk, branches, bark, roots, flowers and fruit are all made up of these cells. In different plants they differ vastly in shape, size, thickness of walls and contents. Bacteria are plants consisting of single cells; pines are composed of millions of cells. In all plants also, the protoplasm, which is the central, living, moving, sensitive part of the cell, manufactures different substances, and either packs these in the cell as reserve material, which is the case in the higher plants, or throws them out of the cell altogether as dead waste, which is the case in many of the bacteria.

In order, therefore, to find out more definitely, if possible, the source of the poisons given off by sawdust, we must look more closely at the contents of wood cells.

CELL CONTENTS.

Young cells are filled at first with protoplasm only. As time goes on, sap forms in the cell and accumulates as small drops in the protoplasm. The sap consists of water and nutritive material dissolved in the water. These two stages in cell life are represented in Figures 2 and 3. Somewhat later, other substances which have been formed by the activity of the protoplasm are stored in the cell, along with the protoplasm and cell sap. Among the commonest materials thus stored in cells are sugar, starch, oils, such as olive, castor, linseed and palm oil; resins, gums, jellies, alkaloids, pigments, acids, such as malic, citric, tartaric and tannic, essential oils such as turpentine.

In the pine family there is stored in the wood and bark cells an abundance of crude turpentine and resin. The Norway spruce of Europe furnishes, from cells, turpentine and Burgundy pitch. The yellow pine of the southern United States yields

spirits of turpentine by distillation of the crude turpentine which runs away from the trees when they are tapped. The residue after the distillation is known as resin.

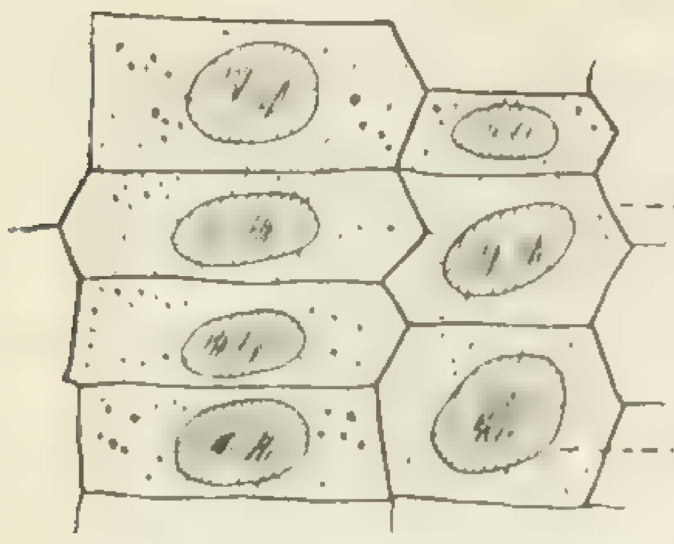

Fig. 2.—Very young cells without cell-sap.

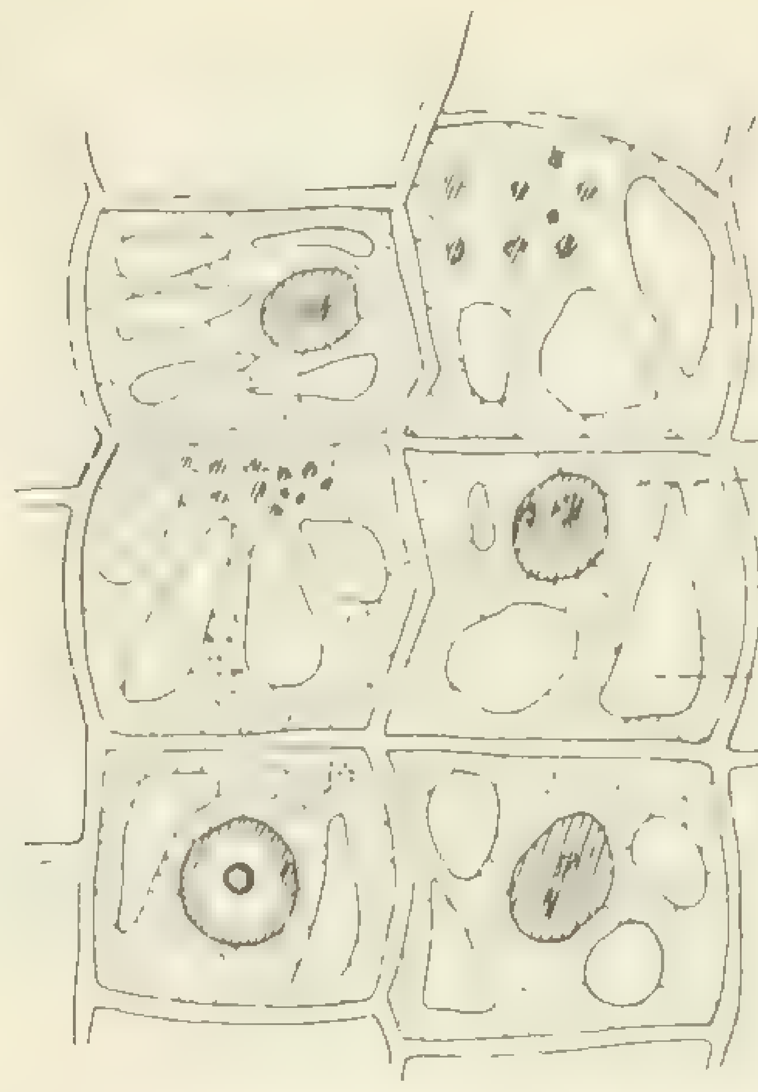

Fig. 3.—Cells showing cell-wall; protoplasmic contents with cell-sap.

Now the source of the poison in the yellowish brown water is unquestionably the material stored in the wood cells. As each cell or vessel is microscopic and contains only a very small quantity of poisonous material, and as the cell wall must be broken open in order to let out the cell contents, it follows that the greater the number of cells that are opened, the greater will be the quantity of turpentine, tanin, &c., poured out. Hence a saw-log completely converted into sawdust would give out the maximum of poison, whereas a similar log sawn into boards, slabs and edgings would give out a much less quantity. Pulp mills will give out the maximum of stored material. So will beet-sugar factories.

The total waste in manufacturing saw-logs into inch boards varies from 25 per cent to 35 per cent of the whole log. Of this total waste, about 13 per cent is sawdust. The proportion of refuse varies (1) with the size of the logs, (2) with the kind of lumber into which the logs are sawn, and (3) with the width of the cut made by the saw.

PULP MILL POISON.

My St. Andrew's experiments determined the percentage of poison from a sulphite pulp mill which is fatal to fish life, but so far as I know, the percentage of poison from a mechanical mill has never been determined. A provisional conclusion, however, may be fairly based upon some of my experiments to be described later in this paper.

QUANTITATIVE DETERMINATIONS.

A quantitative determination of the solid matter contained in the yellowish brown water was made by evaporating 1,000 c.c. of it, at 100° C., in a platinum crucible, and then weighing the rest.

The following results were obtained from white pine solution:—

	M.gs.
1. Solid matter from 1000 c.c. water, the sawdust soaking for four days.	1160
2. Same sawdust with the first water filtered off, and fresh water added and allowed to stand for five days. Solid. .	260
CEDAR SAWDUST.	
1. Solid matter from 1000 c.c. water, the cedar sawdust soaking for four days.	1220
2. Same sawdust with first water filtered off, fresh water added and allowed to stand five days.	470
3. Same operation repeated. Soaking five days	270

These determinations indicate clearly enough that the stored material in wood cells comes away in diminishing quantity every time fresh water is added to sawdust.

WHITE PINE.

A long series of experiments were made with water obtained by soaking 360 grams of white pine sawdust in 7000 c.c. of tap water and changing the water at irregular intervals. During a period of three weeks the water was changed twenty times. In 1,000 c.c. of the twentieth solution, there was found to be 80 m.gs. of solid matter dissolved out of the pine cells. During every day almost of the three weeks, the effects of the poisonous water were tested by immersing fish eggs, adult perch, aquatic worms, tadpoles, copepods, daphnia, hydra, vorticella and black bass fry in the water, and in every instance death followed sooner or later. Sometimes death took place in a few minutes, sometimes in a few hours, the result depending upon the strength of the solution. When air was made to bubble through the poisoned water, the animal lived somewhat longer.

CEDAR SAWDUST.

A similar series of experiments were carried out with cedar sawdust. In this case, 400 grams of sawdust were soaked in 7000 c.c. of tap water. The water was changed 30 times during a period of five weeks, and a 1000 c.c. of the last solution of it—were found to contain 155 m.g.s. of solid matter. The water was tested almost daily by immersing animals in it, just as in the case of pine extracts. The cedar water was found to maintain its poisonous character for a longer time than pine. In other words, cedar wood cells contain more poisonous matter than pine wood cells.

EXTRACTS QUICKLY SOLUBLE.

The experiments hitherto described would seem to indicate that some considerable time was required for the water to dissolve out the poisonous extracts from white pine sawdust, but such is certainly not the case. This was clearly shown in the following experiment, Fig. 4. Two minnows were confined in a bottle containing 600 c.c. water and eighteen grams of white pine sawdust. Fresh water was made to enter and leave at the rate of 100 c.c. per minute. The inlet tube passed straight to the bottom of the vessel, and its lower end was therefore buried in about an inch of sawdust. One animal lived forty minutes, the other fifty. When the incoming water was reduced to 80 c.c. per minute three minnows lived only from three to five minutes. When the fresh water entered at the rate of 125 c.c. per minute, minnows lived from twenty to ninety minutes. The control animals were kept for a week in a similar bottle, without sawdust, of course, and with water coming in at the rate of 110 c.c. per minute. In these experiments the poisonous extracts must have been coming away all the time. The moment the bottle was full of water the minnows were slipped into it. Consequently, when the fish were killed in five minutes, the 600 c.c. at first in the bottle, and 400 c.c. additional water were poisoned. When they were killed in ninety minutes, no less than 11,250 c.c. were poisoned. That is, the percentage weight of sawdust to poisoned water was ·16 per cent. This determination is important, as we shall see later, when we come to compare it with the percentage of sawdust thrown into the Bonnechere river.

Fig. 4.

COMPARATIVE RESULTS.

After obtaining the general results indicated in the preceding part of this paper, it seemed desirable to plan a series of experiments that would show comparative results

at a glance. With this end in view, two grams each of different kinds of sawdust were placed in shallow circular dishes containing respectively, 300, 400, 500, 600, 700, 800, 900, 1,000, 1,200, 1,500 and 1,700 c.c. of fresh water. After soaking for about five hours in each case, a minnow was placed in each of the dishes. The length of time each animal lived was carefully noted, except in those cases where death occurred during the night. The results are given in the following tables:—

White Pine Sawdust.

Weight of Sawdust.	Volume Water c. c.	Time Soaking.	Time at which minnow was immersed.	Results.
2 grams.	300	From 10 a.m.	2.43 p.m.	Lived about 9 minutes.
"	400	"	"	" "
"	500	"	"	" "
"	600	"	"	" "
"	700	"	"	" "
"	800	"	"	" 10 minutes.
"	900	"	"	" 13 "
"	1,000	"	"	" 15 "
"	1,200	"	"	" 20 "
	1,500	"	"	" 29 "
"	1,700	"	"	" 29 "

Ontario Red Pine.

2 grams.	300	10 a.m.	2.47 p.m.	Lived 47 minutes.
"	400	"	"	" 50 "
"	500	"	"	" 50 "
"	600	"	"	" 1 hour and 28 minutes.
"	700	"	"	" 1 " 14 "
"	800	"	"	" 1 " 14 "
"	900	"	"	" 1 " 53 "
"	1000	.	"	" 2 hours and 20 "
"	1200	"	"	" 2 " 50 "
"	1500	"	"	" 3 " 45 "
"	1700	"	"	" 3 " 45 "

Ontario Cedar.

2 grams.	300	From 10 a. m.	2.33 p.m.	Lived 8 minutes.
"	400	"	"	" 9 "
"	500	"	"	" 19 "
"	600	"	"	" 20 "
"	700	"	"	" 21 "
"	800	"	"	" 22 "
"	900	"	"	" 27 "
"	1000	"	"	" 27 "
"	1200	"	"	" 1 hour.
"	1500	"	"	" 1 " et 48 minutes.
"	1700	"	"	" 1 " et 55 "

British Columbia Cedar.

Weight of Sawdust.	Volume Water c.c.	Time Soaking.	Time at which minnow was immersed.	Results.
2 grams.	300	10.15 a. m.	2.51 p.m.	Lived 6 minutes.
"	400	"	"	" 6 "
"	500	"	"	" 15 "
"	600	"	"	" 53 "
"	700	"	"	" 43 "
"	800	"	"	" 1 hour and 9 minutes.
"	900	"	"	Jumped out of dish unnoticed.
"	1000	"	"	Lived 1 hour and 32 minutes.
"	1200	"	"	" 1 " 36 "
"	1500	"	"	" 3 " 50 "
"	1700	"	"	" 3 " 29 "

Hemlock Bark.

Bark.				
2 grams.	300	10.10 a. m.	2.36 p.m.	Lived 55 minutes.
"	400	"	"	" 1 hour and 32 minutes.
"	500	"	"	" 1 " 43 "
"	600	"	"	" 1 " 49 "
"	700	"	"	" 2 hours.
"	800	"	"	" 1 hour and 32 minutes.
"	900	"	"	Jumped out of dish unnoticed.
"	1000	"	"	Lived 2 hours and 18 minutes.
"	1200	"	"	" 3 " 24 "
"	1500	"	"	" 4 "
"	1700	"	"	" 4 " 15 "

Hard Maple Sawdust.

2 grams.	300	From 10, 38 a.m. July 15.	July 15, 3.30 p.m.	Lived 2 hours and twenty minutes.
"	400	"	"	July 21, 10 a.m. Still alive.
"	500	"	"	" 16. Died last night.
"	600	"	"	" 21, 10 a.m. Still alive.
"	700	"	"	" 16. Died last night-
"	800	"	"	" 21, 10 a.m. Still alive.
"	900	"	"	Lived only 2 hours.
"	1000	"	"	July 18. Died between 4 p.m. and 8 p.m.
"	1200	"	"	Lived 3 hours and 30 minutes.
"	1500	"	"	July 18. Died between 4 p.m. and 8 p.m.
"	1700	"	"	July 20. Died 3 p.m.

This experiment was discontinued July 21, 10 a.m.

Ontario Cedar Bark.

2 grams.	300	10.20 a.m.	2.41 p.m.	Lived 37 minutes.
"	400	"	"	" 1 hour and 20 minutes.
"	500	"	"	" 50 minutes.
"	600	"	"	" 50 "
"	700	"	"	" 1 hour and 20 minutes.
"	800	"	"	" 1 " 31 "
"	900	"	"	" 1 " 40 "
"	1000	"	"	" 1 " 57 "
"	1200	"	"	" 2 hours 10 "
"	1500	"	"	" 4 "
"	1700	"	"	" 4 " 20 "

Elm Sawdust.

Weight of Sawdust.	Volume Water c. c.	Time Soaking.	Time at which minnow was immersed.	Results.
2 grams.	300	10.44 a.m. July 15.	3.30 p.m.	Lived 4 hours and 30 minutes.
"	400	"	"	Died 10 a.m. July 16.
"	500	"	"	Lived 1 hour and 30 minutes.
"	600	"	"	" 2 hours and 30 "
"	700	"	"	" 1 hour and 30 "
"	800	"	"	July 21, 10 a.m. Still alive.
"	900	"	"	" 18. Died last night.
"	1000	"	"	" 21. " "
"	1200	"	"	Lived 1 hour and 30 minutes.
"	1500	"	"	" 4 hours and 30 "
"	1700	"	"	" 1 hour and 30 "

This experiment was discontinued July 21, 10 a.m.

Oak Sawdust.

2 grams.	300	Since 10.15 a.m. of 23rd.	July 23. 2.30 p.m...	Lived 2 hours and 30 minutes.
"	400	"	"	" 2 " 30 "
"	500	"	"	" 3 " 30 "
"	600	"	"	" 7 " 30 "
"	700	"	"	" 2 " 30 "
"	800	"	2 animals.	One lived 2 hours and 20 minutes. July 24. Died last night.
"	900	"	3 animals.	One lived 7 hours and 30 minutes. July 24. Died last night.
"	1000	"	"	July 25. Jumped out unnoticed.
"	1200	"	"	" 30, 9 p.m. Still alive. Released.
"	1500	"	"	Lived 3 hours and 30 minutes.
"	1700	"	"	July 25, 3 p.m. Dead.

Ash Sawdust.

2 grams.	300	10.48 a.m. of July 15.	3.30 p.m. July 15...	July 21, 10 a.m. Still alive.
"	400	"	"	Lived 1 hour and 30 minutes.
"	500	"	"	July 21, 10 a.m. Still alive.
"	600	"	"	Lived 1 hour and 40 minutes.
"	700	"	"	Lived 2 hours and 10 minutes.
"	800	"	"	July 21st. Died last night.
"	900	"	"	Lived 1 hour.
"	1000	"	"	July 21, 10 am. Still alive.
"	1200	"	"	July 21. Died last night.
"	1500	"	"	July 21, 10 a.m. Still alive.
"	1700	"	"	July 19. Died to-day.

This experiment was discontinued July 21, 10 a.m.

HEMLOCK SAWDUST.

Weight of Sawdust.	Volume Water c. c.	Time Soaking.	Time at which minnow was immersed.	Results.
2 grams.	300	10.15 a.m. of 23rd.	2.30 p.m. July 23.	July 26, 9.30 a.m. Dead.
"	400	"	"	" " "
"	500	"	"	July 30, 9 a.m. Released.
"	600	"	"	" " "
"	700	"	"	" " "
"	800	"	"	July 26, 9.30 a.m. Found dead.
"	900	"	"	Lived 45 minutes.
"	1000	"	"	July 26, 11 a.m. Dying.
"	1200	"	"	" 28, 3 00, Dead.
"	1500	"	"	Lived 1 hour and 45 minutes.
"	1700	"	"	July 26, 9.30 a.m. Dead.

SPRUCE SAWDUST.

Weight of Sawdust.	Volume Water c. c.	Time Soaking.	Time at which minnow was immersed.	Results.
2 grams.	300	10.30 a.m. of 23rd.	2.40 p.m. July 23 .	Lived 3 hours and 50 minutes.
"	400	"	"	July 24, 9.30 a.m. Found dead.
"	500	"	"	" " "
"	600	"	"	" 26, " "
"	700	"	"	" 24, " "
"	800	"	2 animals.	July 24, 9.00. Dying. " 25, " Found dead.
"	900	"	"	July 26, 9.30 a.m. Found dead.
"	1000	"	"	" 30, 9.00 a.m. Released.
"	1200	"	"	" " " Dying.
"	1500	"	"	" 27, 7.30 p.m. Dying.
"	1700	"	"	" 26, 8.30 a.m. Found dead.

BARK EXTRACTS.

Contrary to opinions expressed in some reports upon sawdust pollution, I found that aqueous extracts from bark of white pine, hemlock and cedar were not nearly so poisonous as the sawdust solutions. The tanin or other material dissolved out from hemlock bark was of course poisonous; but, in a general way, the effect of bark solutions upon adult fish was to kill them by suffocation. The oxidation processes going on in the bark extracts deprived the water of the oxygen usually dissolved in it, and as a consequence fish immersed in it soon died. That this was the true cause of death was evident from the fact that bark solution when aerated, that is, with air made to bubble through it, supported fish life just as well as any normal water would do.

BLACK BASS FRY.

For the successful results obtained in many of my experiments I am indebted to the Department of Marine and Fisheries, Ottawa. On June 27, Mr. Halkett, an officer of the department, brought to me about 100 black bass fry. They had been hatched out in the natural pond at Belleville and were a fine lot of fry, each about an inch long. I placed them in a galvanized-iron tank about 4 feet long, 3 feet wide, the water in it being kept about 3 to 4 inches deep. A copious flow of tap water from Lake Ontario

entered the tank and left it continually. A few flat stones were placed here and there on the bottom.

The larger and more pugnacious ones took shelter beneath the stones, the smaller and more timid ones were forced into the corners of the tank, driven away from the stones by their bigger neighbours. I fed them regularly on small and well washed particles of meat, obtained by mincing small earthworms. These fine particles were flipped into the water. As they slowly sank towards the bottom they were seized by the fry and eaten with great avidity. The tank was always clean, and I had no trouble in keeping the fry alive and healthy.

In catching them for the experiments, I used a dip net. The slower ones were, of course, caught first. At the end of three weeks the survivors had become so expert in dodging the net that they were very difficult to capture. They had grown to about 1½ inches in length and correspondingly heavy. The last few could be caught only by drawing the water off from the tank.

CONTROL EXPERIMENTS.

The general method of conducting the experiments has been already indicated. It consisted in immersing fish eggs, fry, fish food (such as aquatic larvae, worms, tadpoles) and adult fish, in varying strengths of sawdust solutions and noting results. In the vast majority of cases a control animal in tap water accompanied the regular experiment, and observations were made upon both at the same time. Hundreds of small minnows were used as well as the black bass fry already referred to. In some experiments the minnows appeared to be the more robust, in other cases the fry.

CRITICISMS.

In some newspaper criticisms of my work at St. Andrews in 1900, objection was made to the statement that sawdust poisoned the water. The writers held that there was no poison in sawdust, and that it killed fish solely by taking out the oxygen dissolved in the water. They asserted that fish eggs and all forms of fish life were killed by suffocation. To test this statement I took some of the yellowish brown sawdust water and made a large quantity of air to bubble through it. When the air was thus passing through the solution I frequently placed fish eggs, and adult fish in this aerated water, but in every instance eggs and fish alike died. They died, therefore, not from suffocation, but from the effects of the poison passing from the water through their gill filaments, and into their blood. When not kept too long in the extract the fish could generally be resuscitated by placing them in fresh water.

DECAYING SAWDUST.

One objection frequently urged against the practice of throwing sawdust into streams and rivers is that the decaying sawdust imparts such a disagreeable odour to the water that sensitive fish are driven away to other waters not so polluted. It seemed to me, therefore, that some progress might be made towards a definite conclusion in this matter, if sawdust were allowed to stand for several weeks in an aquarium and tested from time to time as to the changes going on in it, and the influence of these upon fish.

With this end in view about 1,000 grams of white pine sawdust were placed in an aquarium three feet four inches long, fifteen inches wide, and filled up to sixteen and a half inches deep with fresh water. This was done June 24. No water was allowed to enter or leave the vessel. No direct sunlight fell upon it.

The usual results followed, viz., a well defined layer of pale, yellow water about three-quarter of an inch deep formed in a few hours and lay at the bottom. On top of this was the perfectly clear layer about fifteen inches deep.

After soaking for two days, bubbles of gas began to rise to the surface of the water, but no attempt was made to analyze it. The bottom yellowish layer had become so dense that no object could be seen across it—a thickness of fifteen inches. Its upper surface was sharply marked off from the overlying transparent water by a thin grayish layer. Microscopic examination of this layer showed it to be swarming with bacteria.

For the information of the general reader it may be explained that bacteria are divided into two classes in relation to oxygen. One class can live only when in contact with air (oxygen). These are known as *aerobic* bacteria. The other class can live only in media from which air (oxygen) is excluded. These are kown as anaerobic bacteria. The anaerobic were present at the bottom of the aquarium, the aerobic, chiefly towards the top. But between these two, were to be found other bacteria which could live and multiply either in the presence or absence of oxygen.

At the end of the week, the water, especially that siphoned off from the bottom, emitted a sweetish aromatic smell. Only about an inch at the bottom had retained the original yellow colour; the next inch had changed to a yellowish brown; then came a grayish layer about one-sixteenth of an inch thick; above this, what had at first been fourteen inches of perfectly clear water had turned to a dark gray, though still quite transparent. Black bass fry placed in the aquarium at this time at first darted to the bottom, but after meeting the poisonous extract once or twice could not subsequently be driven into it. On the contrary they swam along the top with their nose just touching the surface of the water, and behaved as if suffering from lack of air. They lived only about two hours.

Four days after this, black bass fry lived only an hour when placed in the upper 14 inches of water. That they were suffocating was proved by the fact that, on aerating the water, the fry lived in it for 24 hours, and were then apparently well.

In three weeks the upper 14 inches of water had changed to a steel gray colour.

In five weeks the pleasant aromatic odour had given place to a musty disagreeable smell. The laboratory windows being open, mosquito larvæ became numerous in the aquarium and appeared to be feeding upon the bacteria which were very abundant on the surface of the bag, and along the sides of the aquarium.

On July 31, some of the water was siphoned off from the middle of the aquarium and placed outside the laboratory in direct sunlight. Dr. W. T. Connell, Professor of Bacteriology in the University, examined this water on three successive occasions, and compared its bacterial life with that in the aquarium. He found that sunlight and air had killed off those kinds of bacteria which flourish in shade and in absence of oxygen, and stimulated the growth of other kinds of bacteria which flourish in sunshine and moving water. In a fortnight, this water had become odourless, transparent and brownish in colour. Minnows were able to live in it, and soon played havoc with the mosquito larvæ.

The water in the aquarium remained slate-coloured, slimy and foul-smelling for two months longer, when it was thrown out.

SAWDUST BEDS.

No one needs to be told that sawdust undergoing decay in the laboratory and sawdust decaying along the beds of rivers and streams must present different phenomena. In the laboratory experiment, the sawdust is always under water, the water is stagnant, and both sawdust and water are in the shade. Along a stream, sawdust beds are, in spring and early summer, formed under water; late in the season, they are frequently exposed high and dry to the influences of sunshine, shade and wind. Only in shady pools remaining after the spring freshets, could the conditions in decaying sawdust approximate to those in my laboratory experiment. Moreover, there is continually passing over all sawdust beds a slow current of water, which profoundly influences the changes going on in decomposing matter. The running water is slowly and surely extracting the soluble organic matter from the wood cells. Day after day

it is withdrawing the poisonous material, so that it is only a question of time, until every particle of poison is withdrawn from the sawdust. In the course of a few seasons at most, nothing can remain, but the perfectly harmless wood fibre.

If my laboratory experiment proves anything, it suggests that bacteria will multiply enormously in old sawdust beds, and will consequently stimulate the multiplication of insect life. If this surmise is correct, it throws light upon a fact which is well known to anglers, viz., that the vicinity of old sawdust beds is a favourite haunt for trout and black bass. Beds composed of freshly made sawdust will drive fish away; but old beds, those which have been leached of their poison, will attract fish, because the sawdust shelters and feeds the larvæ of aquatic insects upon which many fish subsist.

Many anglers could corroborate the following testimony of a writer in *Forest and Stream* :—

'Obviously, in localities where the entire bottom is embedded by sawdust, fish can neither spawn nor feed; but it happens that such deposits do not form on their breeding places, nor is the area of their foraging ground appreciably diminished by their presence. Even in the half-emptied and now useless ponds, the current constantly scours out a central channel through the sawdust, leaving the bottom clear and pebbly; so that, in fact, these local beds are of no more detriment to the fish than so many submerged logs. The trout can range far and wide without encountering them at all. Yet, strange to say—that is, it must seem strange to those persons who take it for granted that sawdust kills fish—the most likely places for the larger trout are these self-same pebbly channels in the old ponds, along whose edges, despite a hundred freshets and ice-shoves, the persistent sawdust and tanbark lie in wind-rows so deep that the wader feels as if he were going to sink out of sight whenever he puts his foot into the yielding mass, every movement of which stirs up a broadening efflorescence which spreads for rods away, distributing itself throughout the stream.'

NUTRITIVE RELATIONS.

The connection between a few links in the chain of animal life was apparent enough in the decaying sawdust. Wood extracts supported bacteria, bacteria supported mosquito larvæ, and these again supported fish life. A similar relationship exists in nature. Leaves, branches, and trunks of dead trees are decomposing continuously in our forests. Their cell contents are dissolved out by rain and melting snow, and are in part carried away in streams and rivers. Bacterial life is abundant in all woodland streams, and must be important as food for aquatic insects. With the disappearance of our forests, the bacterial life of streams and rivers must change completely in character, and so must the insect life found along their course. And if the insect life dwindles or disappears, so must the fish life which subsists directly or indirectly upon it. But the great destroyer of fish life is man.

INFLUENCE OF MAN.

The Anglo-Saxon has always been a disturbing factor in the balance of life. Forests, game and fish all disappear with his arrival. To get good fishing or good hunting now-a-days one must travel back to unsettled districts. No one expects game to be plentiful along the settled shores of Lake Ontario, but many people are amazed that fish are not abundant in it. They still hug the pleasing delusion that if brooks have been overfished the fish hatchery can restock them. But with the disappearance of our forests it is exceedingly doubtful whether we can ever again, by all the help of hatcheries, overseers and fish commissioners, re-people the streams which have been depleted by man through deforestation and over-fishing. He has upset the balance of life; it can only be fully restored by a return to primitive conditions. When game, therefore, becomes plentiful on the streets of Ottawa city, fish will be equally abundant below the saw-mills of the Chaudière falls. The conditions are almost if not quite parallel.

ON THE BONNECHÈRE RIVER.

A final judgment cannot at present be pronounced upon the poisonous effects of sawdust. These effects must be studied near the mills and along the sawdust beds of various rivers. A three weeks' study of the Bonnechère river, a tributary of the Ottawa, much polluted with mill rubbish, led me to modify very considerably the conclusions which I had based upon my laboratory experiments. I visited the mill represented in two of the illustrations of this report fully expecting that not one fish could survive in such surroundings. But pike were abundant for miles below the mill, and fish (chub) could be caught any day along the side of the submerged driftwood. Stranger still, the fish so caught lived for three hours in a pailful of sawdust water drawn from the very centre of a sawdust bed. A few brook trout had been caught earlier in the season just below the mill when it was running. At the date of my visit, August 20, 1902, the mill had been closed for seven weeks and no sawdust was then passing into the river.

The owner of the mill furnished me with the data necessary to calculate the percentage of sawdust in the water passing his mill every twenty-four hours. The water contained ·004 per cent of sawdust by weight.

Fig. 5.—Sawmill on the Bonnechère River, a branch of the Ottawa. Sawdust and edgings pass into the river from the end of the mill.

Comparing this percentage with that in two of the laboratory experiments described on pages 42 and 43, we find that in one case two grams of white pine sawdust in 1,700 c.c. of fresh water, *i.e.*, ·12 per cent strength, soaking for five hours, killed a minnow in twenty-nine minutes; and in the other case a percentage of ·16 killed in ninety minutes. That is, there was forty times more water in proportion to sawdust in the Bonnechère river than in one of my laboratory experiments in which a minnow lived for ninety minutes.

The strength of a cup of tea depends upon the proportion of tea leaves to water. And in the same way, the extent to which any stream is polluted with sawdust depends mainly upon two things, viz., (1) the quantity of sawdust, and (2) the volume of water into which the sawdust is discharged. No stream, therefore, can be pronounced off-

hand as poisoned by sawdust. Each stream must be studied by itself, and the varying conditions must be understood before a judgment can be pronounced.

Of course, the percentage of sawdust in the Bonnechère is a mere approximation, but it points unmistakably to the conclusion that the sawdust poured into the Bonnechère river is not destroying its fish life. Moreover, in Golden lake, an expansion of this same river, and ten miles above any saw-mill, lake trout used to be very abundant. Every October large numbers were caught in nets along their spawning beds. Now these spawning grounds are reported to be deserted by the fish, and certainly sawdust

Fig. 6.—Slabs, edgings and sawdust, half-a-mile below the mill.

cannot be blamed for their disappearance. Higher up the river, in Round lake, the October fishing is still good, solely because there are fewer settlers and less fishing.

ON THE OTONABEE RIVER.

R. M. Dennistoun, Esq., K.C., of Peterborough, has finished the following interesting account of his observations on the Otonabee river:—

'When I was a boy I fished continuously in the river and caught small perches, chub, suckers, &c. A few years later no fish were caught in the river at all, and there were great beds of sawdust in all the slack water. About the year 1893, the Dominion Government absolutely prohibited the placing of sawdust in the river. At this time the little lake at Peterborough was a horrible place. The sawdust lay upon the bottom to the depth of 8 or 10 feet in some places, and the gases which were generated would suddenly burst upwards with such force as to render canoeing unpleasant and even dangerous. It took several years, after the placing of the sawdust in the river had been stopped, to wash out the accumulated deposits, but successive spring freshets accomplished this.

In a very few years we began to notice that small fish were returning; then came the large fish, and now we have excellent fishing for bass, in all parts of the river, right through the centre of the town of Peterborough. We have good maskinonge fishing in the little lake which is adjacent to the town, and which was formerly nearly filled with sawdust. I can now go down on a June morning to the river just below my house, and cast a fly with invariable success, and no amount of theory or argu-

ment would shake my knowledge of the fact that this is due entirely to the removal of the sawdust from the river. There are now several fishing clubs in Peterborough. The Peterborough Lock Company and the Canadian General Electric Company each has a fishing club composed of workmen from the factories. This will satisfy you that the fishing is now worth something.'

The conditions which Mr. Dennistown describes are quite different from those on the Bonnechere. On this river, below where I made my observations, there is a fairly rapid current for 5 or 8 miles, and no slack water or pools excepting at the Douglas dam. The rapid current aerates the water, promotes microbic action upon the wood extracts, and tends to self-purification, whereas on the Otonabee river, the conditions would approximate to those of decaying sawdust in a laboratory aquarium; fish not driven out of the 'slack' water and sluggish lake would lie killed by the poisonous extracts, or suffocated in the water which had lost its oxygen.

ON THE OTTAWA RIVER.

The question of whether the Ottawa river is so greatly polluted with sawdust as to diminish its fish life, has been much debated. Assertions could be obtained in abundance both *pro* and *con*, but assertions prove nothing. The indications are all against the popular idea that sawdust is destroying the fish of the Ottawa.

In the first place, we have the testimony of the chemist. Mr. A. McGill, B.A., assistant analyst in the Inland Revenue Department, in 1890, made an exhaustive series of analyses of the Ottawa river water at two different seasons of the year, and as a result of his investigations reported: 'As to the fitness of the Ottawa water for domestic uses, I may say that it contains nothing that must necessarily render it unwholesome.' If Mr. McGill could find nothing in the water that would be likely to harm human life, it is quite unlikely that fish would be injured by it. At any rate, no one has ever proved that Ottawa river water kills fish, and until this is proved, ordinary mortals may well be excused from believing it.

In the second place, many competent observers living along the banks of the Ottawa claim that fish are not injured by the mill rubbish that has for years been drifted into the river. Mr. W. C. Edwards, M.P., is one of these. Writing to me under date of July 19, 1902, he said. 'I have lumbered on the Ottawa river for thirty years, during which time I have never put sawdust or mill refuse into the stream. I have, however, observed what has been going on, and it is not my observation that sawdust has anything to do with deteriorating the number of fish in the river. We have the same kinds and about the same quantity of fish in the Ottawa as we had twenty-five years ago. We think a wonderful lot of nonsense has been preached with regard to this matter. Conditions may possibly be different in very small streams, but so far as the Ottawa is concerned, if we had double the saw-mills on it that it has, and if all the sawdust went into the stream, neither the fishing interests nor navigation to any appreciable extent would be injured.'

Mr. Hiram Robinson, president of the Hawkesbury Lumber Company, writes: 'While we were putting sawdust into the Ottawa at this place, I never knew fish to be affected by it, having frequently seen good sturdy fish caught in our ponds just below the mill.' Sawdust is not now drifted into the river by this company.

Taken along with the opinions of Professor Prince and Mr. S. T. Bastedo, the observations of Mr. Dennistoun upon the Otonabee river, and of Messrs. Edwards and Robinson upon the Ottawa show how necessary it is that a thorough investigation should be made into the whole subject.

My own conclusions, based upon laboratory experiments, may be summarized as follows:—

CONCLUSIONS.

1. Strong sawdust solutions, such as occur at the bottom of an aquarium, poison adult fish and fish fry, through the agency of compounds dissolved out of the wood cells.

2. The overlying water in such an aquarium does not at first kill fish. After about a week it does kill, but solely through suffocation, the dissolved oxygen having all been used up.

3. Bacteria multiply enormously throughout all parts of such an aquarium, and through oxidation change the poisonous extracts to harmless compounds. Mosquito larvæ live on the bacteria. No doubt, in natural pools, other aquatic insect larvæ live on bacteria also.

4. Subsequent aëration and sedimentation of sawdust water purify it, so that fish can live in it without injury.

5. Since adult fish and black bass fry both refused to be driven into pine extracts in the bottom of an aquarium after they had experienced its poisonous effects, we may infer that fish would desert a river much polluted with freshly made sawdust, going down stream and into tributaries to escape from the disagreeable influence of the sawdust extracts.

6. Further observations and studies along sawdust polluted streams and rivers in Canada are urgently needed before more definite conclusions can be reached. My own observations on the Bonnechere are not sufficient to enable me to form any conclusion that would be applicable to other rivers. In this connection I should like to quote Professor Prince again: ‘Circumstances modify the effects of all forms of pollutions, so that waste matters which would be deadly in one river will pass away and prove of little harm in another, where the conditions are different.’

ACKNOWLEDGMENTS.

I must add finally, acknowledgment is due to Toronto University, the Public Library, Toronto, and the Canadian Institute, for the privilege of consulting their libraries in order to write the historical part of this report.

I am under special obligations to my colleague, Prof. J. C. Connell, M.A., M.D., for the large supply of minnows which he procured for me, and which were so indispensable for the laboratory experiments.

Dr. John Waddell and Mr. C. W. Dickson, M.A., both of the School of Mining, Kingston, rendered valuable aid in determining the amount of solid matter in sawdust water.

The Ontario Fisheries Department greatly facilitated my task on the Bonnechere by instructing their overseers to assist me in every way possible.

APPENDIX TO DR. KNIGHT'S REPORT ON SAWDUST AND FISH LIFE.

Bacteriological Examination of Sawdust Water in Shade and in Sunshine.

Examination of sawdust water in aquarium made July 31, 1902.

Two agar plates made. The first averaged 3,300 colonies of bacteria per cubic centimetre. None of the colonies were spirilla which were present in large numbers in direct microscopic examination of the water. The chief colonies were those of a spore bearing bacillus, a variety evidently of B. Subtilis; also a few sarcinae, par-

ticularly one like Sarcina Lutea. The second plate averaged 3,570 colonies per cubic centimetre. In general characters they were the same as in the first plate.

August 4, 1902. Water in aquarium. Agar plates averaged 3,570 colonies per cubic centimetre. These were in all respects like those of July 31.

Same water in sunlight since July 31. Agar plates average 4,200 colonies per cubic centimetre. These colonies contain the same bacteria as in the aquarium water, but in fewer numbers. Further, there is present a fluorescent bacillus, making up half the number of colonies present.

August 8, 1902. Water in aquarium. Agar plates develop 7,870 colonies per cubic centimetre. These colonies are of the same type as those found on previous plates with the addition of about 1,000 colonies of B. Mesentericus Vulgatus per cubic centimetre.

Water in sunlight. Agar plates develop 37,070 colonies per cubic centimetre. These consist mainly of B. Fluorescens Liquescens; also of Sarcina Lutea, and an occasional colony of B. Subtilis.

W. T. CONNELL,
Prof. of Bacteriology.

V

THE DIATOMACEÆ OF CANSO HARBOUR, NOVA SCOTIA.

A PROVISIONAL LIST.

By Dr. A. H. Mackay, Superintendent of Education for Nova Scotia.

The following determinations of *Diatomaceæ* from Canso harbour were made from collections taken on September 10, 1902, just before leaving the Marine Biological Laboratory of Canada for the second and last time during the season. One collection was from the scrapings and washings of *Zostera marina* L. in the shallow water near the laboratory, the other from the drippings and washings of *Chorda filum* L. a few hundred yards to the east of the laboratory. In addition I was given a small vial of a schizonematous diatom growing in minute gelatinous colonies which mimic minute species of *ectocarpus*, &c., collected by Mr. C. B. Robinson on the piles of some of the wharves.

As my previous studies of the *Diatomaceæ* were confined to those found in fresh-water deposits, I required more time than I could afford to make a complete study of the rarer species in the collections before the date given me to complete my report. In addition I had the misfortune to be accidentally without any lens of higher power than a one-twelfth inch oil immersion, so that I was unable to make out some of the finer details necessary to determine some of the species, or to measure the number of striæ when more numerous than fifteen to ten microns.

My reference authorities are as follows: 1. 'Diatomaceen Typen-Platte,' No. 484 of J. D. Moller, Wedel in Holstein, April, 1878, containing about 400 types. 2. A. Schmidt's 'Atlas de Diatomaceenkunde,' up to plate 160. 3. George Karsten's 'Die Diatomeen der Kieler Bucht.' 4. Rabenhorst's 'Flora Europæa Algarum Aquæ Dulcis et Submarinæ.' 5. Van Heurck's 'Synopsis (et Atlas) des Diatomées de Belgique.' 6. Peragallo's 'Diatomées Marines de France,' in 'Le Micrograph Préparateur' to date. 7. Wolle's 'Diatomaceæ of North America.' 8. 'Le Diatomiste,' volumes I. and II., 1890 to 1896. 9. 'Diatomées Fossiles du Japon' by Brun of Geneva and Témpere of Paris. 10. 'Diatomées des Alpes et du Jura et de la Region Suisse et Francaise des Environs de Geneve,' par J. Brun.

A few plankton forms were taken in the collections and also some fresh-water species. But from the *Chorda filum* the great mass consisted of *Striatella unipuncta* Ag. and *Licmophora Lyngbyei* (Kg.) Grun., forming more than 90 per cent probably of the whole mass of diatomaceous material. Several species were seen but lost before determination. I, therefore, present the following list as a provisional one; and propose to still further examine the material from Canso, and to supplement it by a study of the *Diatomaceæ* of Halifax harbour, which I am in a position to be able to explore with more convenience.

The dimensions—length and breadth of valve—are given in microns, which for the sake of compactness are expressed simply in figures. Likewise, the number of striæ, ribs or rows of pearls in 10 microns are given in figures simply.

PROVISIONAL LIST.

1. Amphora ———————— (?).
2. Cymbella ———————————— (?).
3. Stauroneis anceps Ehr., 18 × 6. One specimen.

4. Stauroneis ventricosa Kg., 45 × 9. One specimen.

5. Navicula viridis Kg., 100 × 18, Ribs 7 or 8 to 10 microns. Only one specimen.

6. Navicula acuminata W.S., 87 × 10, Striæ very fine. One specimen.

7. Navicula cancellata Donk., 52 × 24 to 58 × 26. About 40 ribs, 6 to 10 microns. In *Chorda filum* collection.

8. Navicula distans W.S., Fragments. Striæ 4 or 5. Two specimens.

9. Navicula didyma Ehr., 45 × 19 to 70 × 25. Striæ about 8. The dimensions are more fully expressed as follows, ranging from 45 × (19:16:19) to 70 × (25:19:25), the middle figure within the bracket indicating the breadth at the middle. Common in the *Zostera* collection.

10. Navicula entomon Ehr., 39 × (14:9:14) to 77 × (24:17:24). Striæ 10 or 11. Not so common as *N. didyma* in the *Zostera* collection.

11. Navicula Smithii Breb., 67 × 40 to 70 × 42. Striæ 6 or 7. Not common.

12. Navicula forcipata Grev., 45 × 20. Rare.

13. Navicula aspera Ehr., 100 × 24 to 120 × 25. Striæ from 19 to 13. Somewhat common.

14. Navicula Baileyana A. S., Var. (?). 63 × 33. Striæ 9 or 10. This may be a variety of the following. One specimen.

15. Navicula marina Ralfs., 80 × 33. Striæ 9. One specimen.

16. Navicula corymbosa Ag., 21 × 3.5 to 27 × 5.5. Striæ very fine. Averaging 24 × 5. They grew massed on filamentous fronds of gelatine which subdivide like minute branching olive colored seaweed, attached to the piles supporting the wharves. This is a *Schizonema* of the older writers, and does not appear to be very different from the following species, according to Rabenhorst. Karsten differentiates them more widely.

17. Navicula ramosissimum Ag., 30 × 4.5 to 30 × 6. Striæ 13. Found with the above, of which it may be a variety.

18. Navicula mollis W.S., 40 × 6. Found sparingly with the above; but whether it is a distinct species or not is a matter of doubt.

19. Navicula pelliculosa (Breb.) Hilse., 13 × 11. Striæ invisible with a one-twelfth oil immersion lens.

With further study the last four determinations may require to be revised. A stronger lens and a study of the plants in their habitat may give additional information. There appears to be a lack of agreement in important particulars between the ideas held of these species by several of the authorities named above.

20. Pleurosigma decorum W.S., 220 × 27 to 240 × 35. Oblique striæ cutting at about 70°. Oblique striæ 12 or 13; horizontal about 15 ±.

21. Pleurosigma Aestuarii S.W., 97 × 23. Striæ just visible in the one-twelfth. This looks also very much like *Pl. latum*, Cl. as figured and described by Peragallo. One specimen observed.

22. Pleurosigma Balticum W.S., 270 × 30. Several specimens seen.

23. Rhoicosigma ———————————— (?).

24. Rhoicosphenia curvata (Kg.) Grun. Var. marinum, 30 × 12 to 35 × 12. Striæ 15 ±.

25. Achnanthes subsessilis Kg., 56 × 9 to 60 × 20. Striæ 8 or 9. Not very rare.

26. Achnanthes longipes Ag., 80 × 33. Large striæ 6 in 10 microns with two rows of pearls between each. Small striæ about 14. Rare. Found only with the *Navicula corymbosa* material.

27. Cocconeis scutellum Ehr., 20 × 12 to 27 × 18. Rows 12. Very common.

28. Cocconeis costata Greg., 11 × 6 to 18 × 7.5. Striæ about 10. Common. Can hardly be a variety of the preceding species.

29. Cocconeis ambigua Grun., 12 × 5 to 13 × 7. Doubtful.

30. Eunotia ——————— (?)., 69 × (5:6:7:6:5). Striæ 13. Comes near *Eunotia pectinalis* (Kg.) Rab.; but the centre is swollen symmetrically both above and below the general arch. That is the ends are about 5 microns, the general length about six microns thick, while the middle swells abruptly to about 7 microns in thickness.

31. Eunotia ———— (?)., 21 × 14, striæ about 15. One specimen.

32. Synedra affinis (Kg.), 75 × (3.5:4:3.5) to 90 × 3.5, Striæ 13. Not uncommon in *Chorda* collection.

33. Synedra Gallionii, Ehr., 240 × (6:7:6) to 300 × (7:8:7). Striæ 10 or 11. Rather common in *Chorda* and also *Zostera* collections.

34. Synedra crystallina (Lyngb.) Kg., 375 × (9:8:11:8:9) to 600 × (10:8:13:8:10). Striæ 15 +. Common.

35. Synedra fulgens (Kg.) W. S., 240 × (9:7:10:7:9) to 340 × (10:8:12:8:10). Striæ 12 to 14 or more. Karsten's *S. crystallina* does not appear to agree with Moller's type nor with the descriptions and figures in Van Heurck and Wolle, for instance. Van Heurck's *S. fulgens* is practically a reduced *S. crystallina*. Many of the specimens in these collections where *S. fulgens* is very common, while retaining the general shape of the larger species, have the striation generally coarser instead of finer. At least this appears from a large number of estimates if not exact measurements which I noted.

36. Synedra undulata (Bailey) Greg. 550 × (7:4:9:4:7). Striæ about 12. Only one specimen of this splendid species has been noted, and it is in close agreement with the type.

37. Homœocladia capitata H. L. S. 22 × 3. Striæ 12 ±. From its smallness the determination of this species may be considered doubtful.

38. Fragillaria hyalina (Kg.) Grun. (?).

39. Fragillaria Pacifica, Grun. 25 × 6. Striæ 15. (?).

40. Fragillaria amphicephala Ehr. 45 × 11. Striæ not visible in the 1-12. Doubtful, as only one specimen was noted.

41. Licmphora Lyngbyei (Kg.) Grun. 40 × (12:3) to 60 × (24:3) to 80 × (8:2). Striæ about 15 or less. This is the species which next to *Striatella unipuncta* is the most abundant in the *Chorda* collection. It is possible that the variations of proportion observed may be too great for combination into one species. A separation of the species, if there are more than one, requires more investigation of the plants in their habitat.

42. Licmophora ———— (?). Somewhat ovate-fan shaped like *Podosphenia Baileyi* of Edwards. Roundish but drawn at the base into a cuneate stem. Height and breadth varying from 40 × 25 to 50 × 28 to 54 × 33 to 66 × 47 to 67 × 45. A central line, sometimes doubled runs like the midrib of a leaf through the delicate frond which generally shows under the 1-12 oil immersion, a faint striation at right angles to the midrib, which striation becomes fainter as it ascends until it becomes invisible before the middle of the frond is reached. It does not appear to be strongly silicified, for prolonged boiling in nitric acid decomposes it. When heated on the cover glass before being mounted in balsam it is more or less distorted. Lack of time has prevented my complete study of the form; so that I can merely say it may be a diatom, and it may not.

43. Grammatophora marina (Lyngb.) Kg. 30 × 10 to 40 × 15 to 42 × 9. Striæ often not visible in the 1-12th. Common.

44. Grammatophora Oceanica Ehr. 54 × 9 to 70 × 15 to 75 × 12. Striæ invisible. Not uncommon. Looks often like *Gr. stricta,* Ehr.

45. Grammatophora ———— (?) 30 × 15 to 45 × 16. Striæ: 12 to 13. Like a variety of *Gr. angulosa* Ehr., or of *Gr. serpentina* Ehr. with the serpentine line shortened to three undulations—a Greek *e* depending from a stemmed hook.

46. Striatella unipuncta Ag. Valves 60 × 18 to 80 × 20 to 87 × 24. Groups 78 to 107 microns across. The most abundant diatom, especially in the *Chorda* collection.

47. Rhabdonema arcuatum Kg. Valves 30 × 14 to 57 × 30 to 70 × 21. Groups across valves 54 to 73 to 105. Striæ 6 to 8. Common.

48. Nitzschia punctata (W.S.) Grun., 44 × 18 to 50 × 18. Rows of pearls 8 to 10 microns. With the *N. corymbosa* collection.

49. Nitzschia vermicularis (Kg.) Grun., 165 × (9:12:9 to 175 × 13 to 210 × (7.5:9.5:7.5). Pearls about 7.

50. Nitzschia lanceolata W. S., 140 × 12. Pearls about 6 to 10 microns. One specimen in *Zostera* collection.

51. Nitzschia plana W. S., 150 × 17. Striæ (coarse and fine) 7 and 18. One specimen noted.

52. Nitzschia Sigma W. S. Var. intercedens Grun., 280 × 8 to 295 × 15. Striæ about 6. Not uncommon.

53. Nitzschia Closterium W. S., 120 × 6. Not strongly silicified.

54. Nitschia paradoxa Grun., 100 × 5. An interesting plankton species.

55. Surirella Gemma Ehr., 108 × 50. Costæ 2 or 3 to 10 microns. One specimen.

56. Campylodiscus decorus Breb. One specimen.

57. Campylodiscus————(?). Suborbicular, 50 microns in diameter. Marginal costæ against larger and smaller parts of circumference about 2 or 2.5 to 10 microns. Subcentral area 50 × 22 with striæ running from ends of costæ into a slightly curved and eccentric diameter line; 10 striæ to 10 microns. Approaches *C. Thuretii* Breb. and *C. Samoensis* Grun. Van Heurck's description of *C. Thuretii* applies exactly to the specimen, although the figure given in the Atlas shows something like three pseudoraphes instead of the one referred to above as the curved excentric diameter.

57. Chætoceros Janischianum (?). A plankton form of which one specimen was observed in a mount from one of the collections.

58. Melosira distans Ag. Diameters 9 to 14. Length of joints 5 to 7.

59. Melosira sulcata Kg. (?).

60. Melosira sculpta Ehr., 21 to 24 in diameter. Joints or frustules 5 to 6.

61. Melosira granulata (Ehr.) Ralfs. 18 to 22 in diameter, 48 points around circurference of frustule. Frustule 18 × 6. Rows of granules 9 in 10 microns.

62. Melosira nummuloides Ag. Diameter 12 to 27 microns. Quite abundant in the *N. corymbosa* material. Very faint, irregular and defective longitudinal wavy striations, closer than one micron when not defective, just visible on the frustules.

63. Biddulphia aurita (Lyngb) Breb. (12 + 15 + 10) × 16.5, (12 + 18 + 12) × 24, (12 + 14 + 11) × 27, (10 + 12 + 11) × 30. Rows of points about 10 in 10 microns, and uniform over middle segment and end segments. The type of this species in Moller's Typen-Platte, has larger granules or points on the domed end segments.

64. Biddulphia Roperiana Grev. (14 + 28 + 12) × 37 to (18 + 23 + 13) × 62. Rows of points about 7 to 8 on cylinder, more crowded on domes. These two last species are not uncommon; and they look so much alike that it is a question if they should not be considered two varieties of the same species.

65. Triceratium ————(?). Specimen 12 microns in diameter.

66. Auliscus ————(?) One specimen seen but lost.

67. Actinoptychus undulatus Ehr. (?).

68. Actinocyclus ————(?). Diameter 45 microns.

69. Hyalodiscus subtilis, Bailey. Diameter 24 to 27. Dark center 8 to 10.

69. Cyclotella operculata Kg. (?). Diameter 12 microns.

70. Coscinodiscus radiatus Ehr. Rare.

71. C. robusta Grev. Fragment. Each alveolus 3 microns in diameter.

72. C. excentricus Grun. (?). Diameter 25 microns.

73. C. concavus Ehr. (?) 45 microns in diameter.

VI

REPORT ON THE FLORA OF CANSO, NOVA SCOTIA.

BY PROF. JAMES FOWLER, LL.D., F.R.S.C., QUEEN'S UNIVERSITY, KINGSTON.

During the summer of 1901 the writer enjoyed the privilege of spending a part of the season (June 28 to August 26) at Canso, N.S., collecting specimens of the flora occurring in the neighbourhood. Through the kindness of Professor Ramsay Wright, assistant director, who had charge of the Biological Laboratory, he was furnished with table, room and other conveniences, and was thus enabled to make it his headquarters during his visit to the locality. The town of Canso is situated on the most eastern point of the mainland of North America south of Labrador, at the entrance to Chedabucto bay, on the sixtieth degree of longitude, and nearly due south of the town of Arichat on Isle Madame. It is consequently exposed to the cool, damp winds and frequent fogs of the Atlantic coast. The district around is composed very largely of barren rocks and bogs varied by the presence of a few huge mounds of glacial debris. Two of these, rising respectively to the height of 119 and 117 feet, furnish an imposing background to the eastern part of the town. Every visitor who wanders over these heights on a clear summer day must be impressed by the grandeur of the view. Northwards the eye wanders over a vast extent of sea and islands across the bay to Isle Madame in Cape Breton; on the west and south the expanse of rock and bog and hill stretches away to the distant horizon, and on the east a few islands lie near the shore, and the great ocean stretches away beyond. The large number of fishing vessels and boats in the harbour at all times give it a very lively and pleasing appearance.

PECULIARITIES OF THE VEGETATION.

1. The first peculiarity that attracts the attention of the visitor, especially if he is interested in botanical pursuits, is the almost total absence of trees as far as the eye can see. No shade trees are planted, their absence being abundantly compensated for by the cool sea breezes and fogs. Two species of European Willows (*Salix viminalis, L.,* and *S. fragilis,* L.) are common near dwelling houses and seem to have been introduced by the early settlers. The ancient forest has been all cleared away by the axe and the fires of previous generations, and over a large area only bare rocks and intervening bogs greet the eye. The glacial mounds, mentioned above, constitute nearly the whole of the cultivated land and have been partially transformed into grass fields. At Hazel Hill, about a mile and a half distant, the prospect is much more cheerful. The beautiful houses erected by the Commercial Cable Company for their employees, are situated on the side of a hill, and command an extensive view of hills and lakes and barren plains and bogs.

2. Another notable characteristic is the prevalence of low, stunted forms of vegetation, not only on the rocks, but on the shores and the hillsides. Herbaceous species which should attain a height of two or three feet are dwarfed to a few inches, except in specially sheltered positions. The most common species of pine (*Pinus divaricata,* Ait., *P. Banksiana,* Lambert) sends down its roots into the clefts of the rocks and spreads over the surface, producing abundance of flowers and cones before it attains

a height of three feet above the ground. Spruce and fir trees, only a few feet in height, produce thick, strong trunks to resist the winter gales to which they are exposed, and furnish a suitable shelter around their base for a few lowly forms such as the Twin-flower (*Linnæa borealis,* L.) and the little wintergreen (*Pyrola secunda pumila,* Gray.) The prostrate form of the Juniper (*Juniperus nana,* Willd), the Crowberry (*Empetrum nigrum,* L.) and two species of cranberries are exceedingly abundant, where suitable ecological conditions prevail. In exposed situations, where other plants are often wanting, the three-toothed cinque-foil (*Potentilla tridentata,* Ait.) often covers the surface and continues flowering during the whole summer. Portions of many of the bogs are brilliant with the pitcher plant (*Sarracenia purpurea,* L.) or with the two beautiful orchids *Limodorum tuberosum,* L., and *Arethusa bulbosa,* L. The Baked-Apple Berry (*Rubus Chamæmorus,* L.) is also exceedingly abundant. The bogs are covered with various species of Sphagnum, whilst a few native grasses, intermingled with imported species, form a thick sward, wherever sufficient soil exists to secure a foothold.

3. The exceedingly small number of introduced weeds in the town and the neighbouring districts is another striking peculiarity. No large areas occur covered with buttercups (*Ranunculus acris,* L.) or Dandelions, as in many districts in the Dominion. Even thistles are confined to a very few exceedingly limited spots. Only a single specimen of *Senecio Jacobæa,* L. (the stinking Willie of Pictou), which is such a pest to the farmers in some other localities, especially in the county of Pictou, was seen during the whole season. The sheep sorrel (*Rumex Acetosella,* L.) so abundant elsewhere was difficult to find. In a small patch of wheat near Hazel Hill—the only patch seen in the neighbourhood, the common Corn Spurrey (*Spergula arvensis,* L.) had found a temporary foothold, having been sown, no doubt, with the grain. The Ox-eye Daisy (*Chrysanthemum Leucanthemum* L.) and the Plantain (*Plantago major,* L.) were probably the most abundant of the introduced weeds. The field mustard (*Brassica arvensis,* L.) which has taken possession of many farms in Ontario, was only conspicuous by its almost complete absence.

CAUSES OF THE SMALL NUMBER OF SPECIES.

The existence of these peculiarities naturally suggests inquiry into the causes to which they owe their existence. The following seem to be the most influential factors producing the present condition of the vegetation:—

1. 'A very high authority on the natural sources of our Dominion once explained to Lord Lansdowne, in answer to an inquiry, that the chief industry of Canadians was the destruction of forests.'* The early settlers were compelled by force of circumstances to fell the forests to procure materials for buildings, and also for fuel. Fires are always necessary for the clearing of land, and generally spread over the whole area where brush or fallen trees furnish combustible supplies. Where the soil is thin, or consists of humus produced by decaying vegetation, the whole surface may be destroyed, and only bare rock remain where a dense forest growth had previously existed. At the present time, whenever a young tree attains sufficient size to be of any service for any purpose it is immediately cut down and removed. The destruction of the trees necessarily involves the destruction of all the species of plants that grow under their shade, and of all the mosses, lichens and fungi that find a congenial home on their trunks and roots. The exposure of the rocky surfaces to the fierce winds of winter prevent the growth of even the lowest forms of vegetation, except in sheltered situations. These facts account for the small number of native species occurring in the neighbourhood.

2. Very little cultivated land exists in the neighbourhood of the town. A few grass fields on the glacial mounds, and a very limited number of gardens, constitute

* W. H. Muldrew, Sylvan, Ontario, p. 3.

the whole area subject to cultivation. As a consequence, no importation of foreign grains with their accompanying weeds takes place. The lack of railway communication also prevents the introduction of the many species of weeds which travel by train, and accounts in a large measure for the fact that so few foreign plants have reached the locality.

3. The domestic animals enjoy the liberty of the streets and wander over the uncultivated lands at will, appropriating every vegetable product suited to their taste. The species of plants fitted for their food are consequently subjected to a severe struggle for existence, and only a few are successful in finding defensive retreats among the rocks, thus securing a precarious tenure of life.

4. The most important ecological factors are the chill sea breezes and the Atlantic fogs. These prevent the growth of many species of plants found in other parts of the province where the average temperature and the amount of sunshine during the summer months are much greater. The ice floes, brought down by the current from the north in spring, lower the temperature of the sea waters and of the atmosphere above them, whilst the heated plains and fields of the interior attract the cool breezes to fill the vacancy produced by the ascending aerial currents. The situation of Canso exposes it to the full influences of the winds from the Atlantic, and renders it a pleasant retreat for those who flee from the heated towns of the interior or of the south.

LIST OF PLANTS COLLECTED AT CANSO, NOVA SCOTIA, JUNE 29 TO AUGUST 24, 1901.

By Prof. James Fowler.

Note.—The nomenclature is that of Brown and Britton, Illustrated Flora.

I. Ranunculaceæ.

1. Coptis trifolia (L.) Salisb.
2. Oxygraphis Cymbalaria, Prantl.
3. Ranunculus acris, L.
4. Ranunculus repens, L.
5. Thalictrum polygamum, Muhl.

II. Nymphaeaceæ.

6. Castalia odorata, Woodv.
7. Nymphæa advena, Soland.

III. Sarraceniaceæ.

8. Sarracenia purpurea, L.

IV. Cruciferæ.

9. Brassica arvensis (L.), B.S.P.
10. Bursa Bursa-pastoris, Britton.
11. Cakile edentula (Bigel.), Hook.

V. Violaceæ.

12. Viola blanda, Willd.

VI. Caryophyllaceæ.

13. Alsine graminea, (L.) Britton.
14. Alsine media, L.
15. Ammadenia peploides.
16. Cerastium vulgatum, L.
17. Moehringia lateriflora, L.
18. Sagina nodosa, (L.) Fenzl.
19. Sagina procumbens, L.
20. Spergula arvensis, L.
21. Tissa marina, (L.) Britton.
22. Tissa rubra, (L.) Britton.

VII. Hypericaceæ.

23. Hypericum Canadense, L.
24. Triadenum Virginicum, (L.) Raf.

VIII. Geraniaceæ.

25. Oxalis Acetosella, L.

IX. Ilicineæ.

26. Ilex verticillata, (L.) Gray.
27. Ilicioides mucronata, (L.) Britton.

X. Sapindaceæ.

28. Acer rubrum, L.

XI. Leguminosæ.

29. Lathyrus palustris, L.
30. Trifolium pratense, L.
31. Trifolium repens, L.
32. Vicia Cracca, L.

XII. Rosaceæ.

33. Amelanchier alnifolia, Nutt.
34. Amelanchier Canadensis, L.
35. Aronia nigra, Britton.
36. Crataegus oxyacantha, L.
37. Fragaria Virginiana, Mill.
38. Potentilla Anserina, L.
39. P. Canadensis, L.
40. P. Monspeliensis, L.
41. P. tridentata, Soland.
42. Prunus Pennsylvanica, L.
43. Rosa humilis lucida, Best.
44. Rubus Americanus, (Pers.) Britton.
45. R. Canadensis, L.
46. R. Chamaemorus, L.
47. R. hispidus, L.
48. R. strigosus, Michx.
49. R. villosus, Ait.
50. R. villosus frondosus, Bigel.
51. Sorbus Americana, Marsh.
52. S. sambucifolia, Roem.

XIII. Saxifragaceæ.

53. Ribes oxyacanthoides, L.
54. R. prostratum, L'Her.

XIV. Crassulaceæ.

55. Sedum roseum, (L.) Scop.

XV..Droseraceæ.

56. Drosera intermedia, Hayne.
57. D. rotundifolia, L.

XVI. Onagraceæ.

58. Chamaenerion angustifolium, Scop.
59. Circæa alpina, L.
60. Epilobium lineare, Muhl.

XVII. Umbelliferæ.

61. Ligusticum Scoticum, L.

XVIII. Araliaceæ.

62. Aralia hispida, Vent.
63. A. nudicaulis, L.

XIX. Cornaceæ.

64. Cornus Canadensis, L.

XX. Caprifoliaceæ.

65. Diervilla Diervilla, (L.) McM.
66. Linnæa borealis, L.
67. Viburnum cassinoides, L.

XXI. Rubiaceæ.

68. Galium tinctorium Labradoricum, Weigand.
69. Mitchella repens, L.

XXII. Compositæ.

70. Achillea Millefolium, L.
71. A. Ptarmica, L.
72. Ambrosia artemisiæfolia, L.
73. Anaphalis margaritacea, Benth. and Hook.
74. Anthemis Cotula, L.
75. Aster acuminatus, Michx.
76. A. nemoralis, Ait.
77. A. Radula, Ait.
78. Carduus arvensis, (L.) Rob.
79. C. lanceolatus, L.
80. Chrysanthemum Leucanthemum, L.
81. Doellingeria umbellata, Nees.
82. Euthamia graminifolia, Nutt.
83. Gnaphalium uliginosum, L.
84. Leontodon autumnale, L.
85. Nabalus albus, (L.) Hook.
86. N. trifoliolatus, Cass.

XXII. Compositæ—Concluded.

87. Senecio Jacobæa, L.
88. S. vulgaris, L.
89. Solidago juncea, Ait.
90. S. neglecta, Torr. and Gray.
91. S. puberula, Nutt.
92. S. Purshii, Porter.
93. S. rugosa, Mill.
94. Taraxacum Taraxacum, Karst.

XXIII. Lobeliaceæ.

95. Lobelia Dortmanna, L.

XXIV. Campanulaceæ.

96. Campanula rotundifolia, L.

XXV. Ericaceæ.

97. Chamædaphne calyculata, (L.) Mœnch.
98. Chiogenes hispidula, (L.) Torr. and Gray.
99. Gaultheria procumbens, L.
100. Gaylussacia dumosa, (Andr.) T. and G.
101. G. resinosa, (Ait.) Torr. and Gray.
102. Kalmia angustifolia, L.
103. Ledum Groenlandicum, Œder.
104. Moneses uniflora, (L.) Gray.
105. Monotropa uniflora, L.
106. Oxycoccus macrocarpus, Pers.
107. O. Oxycoccus, (L.) MacM.
108. Pyrola secunda pumila, Paine.
109. Rhodora Canadensis, L.
110. Vaccinium Canadense, Richards.
111. V. Pennsylvanicum, Lam.
112. V. Vitis-Idæa, L.

XXVI. Primulaceæ.

113. Glaux maritima, L.
114. Lysimachia terrestris, (L.) B.S.P.
115. Trientalis Americana, Pursh.

XXVII. Gentianaceæ.

116. Limnanthemum lacunosum, Griesbach.

XXVIII. Borraginaceæ.

117. Pneumaria maritima, (L.) Hill.

XXIX. Solanaceæ.

118. Solanum Dulcamara, L.

XXX. Scrophulariaceæ.

119. Chelóne glabra, L.
120. Euphrasia Americana, Wettst, var. Canadensis, (Townsend) Robinson.
121. Melampyrum lineare, Lam.
122. Rhinanthus Crista-Galli, L.
123. Veronica serpyllifolia, L.

XXXI. *Lentibulariaceæ.*

124. Utricularia cornuta, Michx.

XXXII. *Labiatæ.*

125. Galeopsis Tetrahit, L.
126. Lycopus Virginicus, L.
127. Prunella vulgaris, L.
128. Scutellaria galericulata, L.

XXXIII. *Plantaginaceæ.*

129. Plantago major, L.
130. P. maritima, L.

XXXIV. *Chenopodiaceæ.*

131. Atriplex hastata, L.
132. Dondia maritima, (L.) Druce.
133. Salicornia herbacea, L.
134. Salsola Kali, L.

XXXV. *Polygonaceæ.*

135. Polygonum aviculare, L.
136. P. Hydropiper, L.
137. P. Persicaria, L.
138. P. sagittatum, L.
139. Rumex acetosella, L.
140. R. occidentalis, S. Watson.

XXXVI. *Euphorbiaceæ*

142\. Euphorbia Cyparissias, L.

XXXVII. *Myricaceæ*

142\. Comptonia peregrina, (L.) Coulter.
143\. Myrica Carolinensis, Mill.
144\. M. Gale, L.

XXXVIII. *Cupuliferæ.*

145. Alnus crispa, (Ait.) Pursh.
146. A. incana, Willd.
147. Betula papyrifera, Marsh.

XXXIX. *Salicaceæ.*

148. Populus tremuloides, Michx.
149. Salix Bebbiana, Sarg.
150. S. fragilis, L.
151. S. viminalis, L.

XL. *Empetraceæ*

152. Empetrum nigrum, L.

XLI. Coniferæ.

153. Abies balsamea, (L.) Mill.
154. Juniperus nana, Willd.
155. Larix laricina, Koch.
156. Picea Mariana, (Mill.) B.S.P.
157. Pinus divaricata, (Ait.) Sudev.
158. Taxus minor, (Michx.) Britton.

XLII. Orchidaceæ.

159. Arethusa bulbosa, L.
160. Gyrostachys gracilis, Bigel.
161. G. Romanzoffiana, Cham.
162. Habenaria blephariglottis, Willd.
163. H. clavellata, (Michx.).
164. H. obtusata, (Pursh.) Richards.
165. Limodorum tuberosum, L.

XLIII. Iridaceæ.

166. Iris Hookeri, Penny.
167. I. versicolor, L.
168. Sisyrinchium angustifolium, Mill.

XLIV. Liliaceæ.

169. Clintonia borealis, (Ait.)
170. Unifolium Canadense, Greene.
171. Vagnera trifolia, (L.) Morong.

XLV. Juncaceæ.

172. Juncus Balticus, Willd.
173. J. bufonius, L.
174. J. Canadensis brevicaudatus, Engl.
175. J. effusus, L.
176. J. pelocarpus, E. Meyer.
177. J. tenuis, Willd.
178. Juncoides campestre, (L.)
179. J. pilosum, (L.).

XLVI. Typhaceæ.

180. Sparganium androcladum, (Engelm.) Morong.
181. S. simplex, Huds.

XLVII. Naiadaceæ.

182. Triglochin maritima, L.
183. Zostera marina, L.

XLVIII. Eriocauleæ.

184. Eriocaulon septangulare, With.

XLIX. Cyperaceæ.

185. Carex abacta, Bailey.
186. C. aquatilis, Wahl.
187. C. Atlantica, Bailey.
188. C. canescens, L. var, disjuncta, Fernald.
189. C. crinita, Lam.
190. C. deflexa, Hornem.
191. C. echinata excelsior, Fernald.
192. C. exilis, Dewey.
193. C. Goodenovii, J. Gay.
194. C. leptalea, Wahl.
195. C. Magellanica, L.
196. C. maritima, Muller.
197. C. pauciflora, Lightf.
198. C. scoparia, Schk.
199. C. scoparia, var. moniliformis, Tuck.
200. C. sterilis, Willd.
201. C. sterilis cephalantha, Bailey.
202. C. stricta, Lam.
203. C. tenera, Dewey.
204. C. tenuis, Rudge.
205. C. tribuloides, Wahl.
206. C. trisperma, Dewey.
207. Eleocharis acicularis, (L.)
208. E. tenuis, Willd.
209. Eriophorum alpinum, L.
210. E. vaginatum, L.
211. E. virginicum, L.
212. Rhynchospora alba, (L.)
213. Scirpus cæspitosus, L.
214. S. cyperinus, (L.) Kunth.
215. S. lacustris, L.

L. Gramineæ.

216. Agropyron repens, (L.) Beauv.
217. Agrostis alba, L.
218. A. hyemalis, (Walt.) B.S.P.
219. Alopecurus geniculatus, L.
220. A. pratensis, L.
221. Ammophila arenaria, (L.) Link.
222. Anthoxanthum odoratum, L.
223. Calamagrostis Canadensis, (Michx.) Beauv.
224. Danthonia spicata, (L.) Beauv.
225. Deschampsia flexuosa, (L.) Trin.
226. Elymus arenarius, L.
227. Festuca ovina duriuscula, (L.)
228. Hordeum jubatum, L.
229. Phleum pratense, L.
230. Poa annua, L.
231. P flava, L.
232. P. pratensis, L.
233. Panicularia Canadensis, (Michx.) Kuntze.
234. Spartina glabra, Muhl.
235. S. patens, (Ait.) Muhl.

LI. Equisetaceæ.

236. Equisetum arvense, L.

LII. Filices.

237. Dicksonia punctilobula, Gray.
238. Dryopteris Noveboracensis, Gray.
239. D. spinulosa, (Ketz) Kuntze.
240. D. intermedia, (Muhl.) Underw.
241. Osmunda cinnamomea, L.
242. O. regalis, L.
243. Pteris aquilina, L.

LIII. Lycopodiaceæ.

244. Lycopodium obscurum, L.

LIV. Hepaticæ.

245. Marchantia polymorpha, L.
246. Ptilidium ciliare, Nees.

LV. Sphagnaceæ.

247. Sphagnum acutifolium, Ehrh.
248. S. purpureum, Schifp.
249. S. cymbifolium, Ehrh.
250. S. recurvum pulchrum, Lind.
251. S. rubellum, Wilson.

LVI. Bryaceæ.

252. Ceratodon purpureus, Brid.
253. Climacium dendroides, Web. and Mohr.
254. Dicranella heteromalla, Schimp.
255. Dicranum majus, Turn.
256. D. scoparium, Hedw.
257. Fontinalis Dalicarlica, B. and S.
258. Leucobryum vulgare, Hampe.
259. Polytrichum commune perigoniale, B. and S.
260. Racomitrium lanuginosum, Brid.

LVII. Lichenes.

261. Alectoria jubata, L.
262. Cladonia cornuta, Fr.
263. C. cristatella, Tuck.
264. C. pyxidata, (L.)
265. C. rangiferina alpestris, L.
266. Parmelia saxatilis, L.
267. Theloschistes parietinus, (L) Norm.
268. Umbilicaria Muhlenbergia, Ach.
269. U. pustulata papulosa, Ach.
270. Usnea barbata, Fr.

LVII. *Algæ*

271. Agarum Turneri, Post. and Rupr
272. Ahnfeldtia plicata, Fries.
273. Alaria Pylaii, Grev.
274. Bangia atropurpurea, (Dill.) Ag.
275. Chondrus crispus, L.
276. Chorda filum, Stack.
277. Chordaria flagelliformis, Ag.
278. Cladophora glaucescens, (Griff.) Harv.
279. Corallina officinalis, L.
280. Enteromorpha intestinalis, Link.
281. Fucus nodosus, L.
282. F. vesiculosus, L.
283. Laminaria dermatoidea, De la Pyl.
284. L. digitata, Lam.
285. L. longicruris, L.
286. L. lorea, Bory.
287. L. saccharina, Lamour.
288. Mastigonema aerugineum, Kirch.
289. Oscillaria.
290. Ptilota plumosa, Ag.
291. Polysiphonia formosa, Ag.
292. P. urceolata, (Dillw.) Grev.
293. Protococcus viridis, Ag.
294. Rhodophyllis veprecula, J. Ag.
295. Rhodymenia palmata, Grev.
296. Scenedesmus caudatus, Corda.
297. S. obtusus, Meyen.
298. Ulva latissima, L.

On August 20 (1901), the writer spent a few hours at Arichat, C.B., and collected specimens of the following plants:—

1. Arctium minus, Schk.
2. Aster junceus, Ait.
3. A. lateriflorus, (L.) Britton.
4. A. Radula, Ait.
5. Callitriche palustris, L.
6. Carex flava, L.
7. Drosera intermedia, Hayne.
8. Dryopteris spinulosa intermedia, Eat.
9. Eriophorum gracile, Kock.
10. E. Virginicum, L.
11. Eupatorium perfoliatum, L.
12. Fucus vesiculosus, L.
13. Funaria hygrometrica, Silth.
14. Habenaria clavellata, (Mich.) Spreng.
15. Hypnum Crista-Castrensis, L.
16. H. cuspidatum, L.
17. H. Schreberi, Willd.
18. H. splendens, Hedw.
19. H. triquetrum, L.
20. Juncus effusus, L.
21. Lycopodium clavatum, L.
22. Phegopteris Phegopteris, (L.) Underw.

23. Polygonum sagittatum, L.
24. Rhyncospora alba, (L.) Vahl.
25. Scirpus nanus, Spreng.
26. Sparganium androcladon, (Engelm.) Morong.
27. Spiræa tomentosa, L.
28. Stachys palustris, L.
29. Tanacetum vulgare, L.

VII

THE SEAWEEDS OF CANSO.

BEING A CONTRIBUTION TO THE STUDY OF EASTERN NOVA SCOTIA ALGÆ'

BY C. B. ROBINSON, B.A., PICTOU ACADEMY.

The month of August spent by me at the Marine Biological Station during its second season at Canso (1902) was almost entirely devoted to the determination of the Marine Algæ.

The region was such as to permit the gathering of species having the most varied habitat, deep-water forms being occasionally dredged in great abundance, while *Laminariæ* and *Fuci,* with their associates, grew nearly everywhere below and between tide marks. Tide pools of varying range and size were also easily accessible, and the quieter coves and the wharves yielded other forms. My available time, indeed, proved quite too short for a complete investigation of this portion of the flora of the district.

The clear water frequently made it possible to see large patches of algæ growing upon the bottom at depths of about ten fathoms. The results obtained by dredging in these and somewhat deeper places indicated that the bulk of this was composed of *Ptilota pectinata,* acting as host, however, to many hydroids and other small animals, besides several species of red algæ. Of the latter, *Delesseria alata* was much the most frequent, though the plant seen thus in greatest quantity upon any single occasion was *Euthora cristata angustata.* *Rhodophyllis dichotoma* was also obtained several times, and four species of *Callithamnion* occurred, of which *C. Pylaisæi* and *C. Americanum* were the most plentiful. A small form of this genus, also one each of *Ceramium* and *Polysiphonia,* were often found upon the larger algæ and upon hydroids. These were always sterile, and could not be identified. On the stouter portions of *Polysiphonia* two microscopic encrusting species also grew, one *Erythrotrichia ceramicola,* the other may be the European *Actinococcus.*

Odonthalia dentata and Rhodomela subfusca were each dredged on a single occasion only.

In deep places under wharves beautiful specimens of *Delesseria sinuosa* could be gathered, and it also was frequently found in the dredge. The corallines were also abundant, and six species of *Polysiphonia* were collected, of which *P. urceolata,* often fruiting, was the most plentiful. The determination of *P. Olneyi* rests upon a few sterile filaments, and may be inaccurate.

But perhaps the most striking fact regarding the red algæ was the comparative scarcity of some of the best known and most widely distributed genera. *Ceramium* was represented by a few filaments; *Chondrus* and *Rhodymenia* were seen but rarely, *Gigartina* only once.

The *Phæophyceæ* constitute much the greater part of the littoral flora, and while not quite equalling the *Florideæ* in the total number of species found, far surpass them in individuals.

Among the *Fuci* were *F. evanescens* and *F. filiformis,* the former washed ashore near the laboratory, the latter gathered in tide pools on Cranberry. *F. serratus,* which rivals *F. vesiculosus* in abundance at Pictou, and which has recently been found on the Cape Breton coast, was carefully watched for, and apparently does not occur.

Chorda filum, everywhere plentiful, grew in great luxuriance in Grassy Cove, the fronds usually exceeding twenty feet in length. *Agarum Turneri* was found in several

localities, *Alaria esculenta* on Cranberry rock only. *Desmarestia viridis* was common both in dredged material and cast up on the shore, *Chordaria flagelliformis* somewhat less so, while *Desmarestia aculeata* was rather rare. *Castagnea virescens* was but once obtained, but the filaments, when examined microscopically, were found to be densely crowded with spores, and very beautiful.

Elachista fucicola was extremely common throughout the month; *Leathesia difformis,* always scarcer, became rare after the first fortnight. A single imperfect specimen of *Chætopteris plumosa* occurred in plankton.

Ectocarpus was represented by six species and varieties, including *E. Chordariæ* and *E. reptans,* the former growing upon *Obelia,* the latter upon *Chorda.* The organism, however, which usually composed the brownish tufts upon the piles of the wharves, was not one of these, but a diatom, *Navicula mollis,* numerous individuals of which were inclosed within tubes of mucilage, thus forming a false filament.

The *Chlorophyceæ* were less carefully studied, and the list is believed to be somewhat incomplete. Six species of *Cladophora* were determined, obtained chiefly from tide pools. A few filaments only were seen of *Chætomorpha Picquotiana,* though upon one occasion a considerable quantity was found of a plant, which, rather resembling *Cladophora* in general appearance, seemed never to branch, and answered well to the description of *Chætomorpha longiarticulata.* The filaments were much more slender and less wiry then those of the other species of this genus. and it was probably a *Rhizoclonium.*

The blue-green algæ listed were found as detached filaments, while examining higher forms, no special effort being made to collect them.

It will be noticed that while *Ptilota, Euthora,* and *Delesseria sinuosa,* usually considered amongst the most beautiful red algæ of north-eastern America, are common, *Chondrus* and *Rhodymenia,* the more useful genera of this group, are unusually scarce. On the other hand, nearly all the brown algæ of commercial importance may be had in considerable quantities.

Prof. Farlow very kindly named for me some species about which I was in doubt, and to him and to all of the gentlemen with whom I had the privilege of working at the station, my most grateful thanks are due for assistance and helpful suggestions.

The following is a detailed list of the species observed:—

SCHIZOPHYTA.

SCHIZOPHYCEÆ (CYANOPHYCEÆ).

Hormogoneæ.

Oscillatoriaceæ.

Spirulina sp.
Oscillatoria subuliformis Harv.
O. subtorulosa (Bréb.) Farlow.
O. sp.

Nostocaceæ.

Sphærozyga Carmichaelii Harv.

Rivulariaceæ.

Calothrix confervicola Ag.
C. crustacea (Schousb.) Born. Thur.

CHLOROPHYCEÆ.

CONFERVOIDEÆ.

Ulvaceæ.

Ulva Lactuca L.
U. Lactuca latissima (L.) DC.
Enteromorpha intestinalis (L.) Link.
E. Linza (L.) J. G. Agardh.
E. Hopkirkii McCalla.

Ulothrichaceæ.

Ulothrix, sp.

Cladophoraceæ.

Chætomorpha Picquotiana (Mont.) Kütz.
Rhizoclonium sp.
Cladophora arcta (Dillw.) Kütz.
C. rupestris (L.) Kütz.
C. refracta (Roth) Aresch.
C. glaucescens (Griff.) Harv.
C. lætevirens (Dillw.) Harv.
C. gracilis (Griff.) Kütz.

PHÆOPHYCEÆ.

PHÆOSPOREÆ.

Ectocarpaceæ.

Ectocarpus Chordariæ Farlow.
E. reptans Crouan.
E. confervoides (Roth) Le Jolis.
E. siliculosus (Dillw.) Lyngb.
E. fasciculatus Harv.
E. littoralis robustus Farlow.

Sphacelariaceæ.

Chætopteris plumosa (Lyngb.) Kütz.

Encœliaceæ.

Scytosiphon lomentarius Ag.

Desmarestiaceæ.

Desmarestia aculeata Lamx.
D. viridis Lamx.

Elachistaceæ.

Elachista fucicola Fries.

Chordariaceæ.

Leathesia difformis (L.) Aresch.
Chordaria flagelliformis Ag.
Castagnea virescens (Carm.) Thuret.

Ralfsiaceæ.

Ralfsia verrucosa Aresch.

Laminariaceæ.

Chorda filum, L.
Laminaria longicruris De la Pyl.
L. saccharina (L.) Lamx.
L. saccharina phyllitis Le Jol.
L. digitata (Turn.) Lamx.
Agarum Turneri (Post & Rupr.).
Alaria esculenta (Lyngb.) Grev.

PHÆOPHYCEÆ—Continued.

Cyclosporeæ.

Fucaceæ.

Ascophyllum nodosum Le Jolis.
Fucus vesiculosus L.
F. evanescens Ag.
F. filiformis Gmelin.

RHODOPHYCEÆ.

Bangiales.

Bangiaceæ.

Erythrotrichia ceramicola (Lyngb.) Aresch.

FLORIDEÆ.

Gigartinales.

Gigartinaceæ.

Ahnfeldtia plicata Fries.
Gigartina mamillosa Ag.
Chondrus crispus (L.) Stack.

Rhodophyllidaceæ.

Rhodophyllis dichotoma Lepch.
Euthora cristata (L.) J. A. G.

Rhodymeniales.

Delesseriaceæ.

Delesseria sinuosa Lamx.
D. alata Lamx.

Rhodymeniaceæ.

Rhodymenia palmata (L.) Grev.

Rhodomelaceæ.

Odonthalia dentata Lyngb.
Rhodomela subfusca Ag.
Polysiphonia urceolata (Dillw.) Grev.
P. Olneyi Harv.
P. violacea flexicaulis Harv.
P. variegata Ag.
P. atrorubescens Grev.
P. nigrescens affinis Ag.

Ceramiaceæ.

Spermothamnion Turneri variabile Harv.?
Callithamnion floccosum Ag.
C. Pylaisæi Mont.
C. Americanum Harv.
C. corymbosum (Engl. Bot.) Lyngb.
Ptilota pectinata (Gunn.) Kjellm.
Ceramium rubrum proliferum Ag.

Cryptonemiales.

Squamariaceæ.

Actinococcus sp.?

Corallinaceæ.

Corallina officinalis L.
Lithothamnion Lenormandi (Aresch.) Fosl.
Phymatolithon sp.

VIII

REPORT ON THE MARINE POLYZOA OF CANSO, N.S.

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The following report embodies the results of about seven weeks' work done at the Marine Biological Station of Canada during July and August, 1902. I collected along the beaches, under wharfs, and on kelp washed on the shore. Some dredging was done in the neighbourhood in from 10-25 fathoms, and one of my best sources was stones, tunicates, sponges, &c., brought up on the trawl of the steamer *Active,* which went out a few miles daily to fish for cod and haddock in 20 to 25 fathoms.

My identification depends almost entirely on Hincks' British Marine Polyzoa, as it, the Challenger Reports and Verrill's Report on Invertebrate Fauna of Vineyard Sound were all the accessible literature at the station on this subject.

FAMILY: ÆTEIDÆ.

Aetea truncata (Landsborough).—A colony intermingled with *Obelia commissuralis* growing on a mussel shell (*Mytilus edulis*) was found under a wharf. It is the branched variety, and is exactly like Hincks' illustration, Plate II., fig. 3, except that the tubular appendage is absent in every case and that it is considerably more branched.

FAMILY: EUCRATIIDÆ.

Gemellaria loricata (Linnæus).—A beautiful, bushy, white tuft, two and one-half inches high, attached to a stone, was taken by the trawler *Active.* There is a tinge of brown on the larger branches, but the greater part is pure white; the pits on the wall are extremely small. I have also seen the brown form in about 20 fathoms. In the form and proportion of parts it answers completely to *G. willisii,* Dawson, as described in Hincks' British Marine Polyzoa, p. 21.

Scruparia clavata, Hincks.—Branches on mussel shells (*Mytilus edulis*) were found under wharfs. Some in single file, some back to back, are found in the same branch.

FAMILY: CELLULARIIDÆ.

Menipea ternata (Ellis and Solander).—The following are my notes on this species: July 20, a small patch found on an ascidian taken at Canso. I find no trace of anterior avicularia; lateral avicularia are very distinct, and there is always a large spine on the peristome just inside this avicularium. The operculum varies a good deal in size and shape, and in many is crenate on the free margin, having two or three rounded teeth; it has a thickened border surrounding a deep, flat centre; the tendrils are very long. August 1, speciments were taken from a stone taken by the trawler *Active* in Chedabucto Bay, in about 12-20 fathoms. There is no grouping in triplets, but about seven zoœcia occupy each internode; the anterior avicularium is quite distinct on the upper zoœcium of each internode, and also on some others. The lateral avicularia are not so prominent as in Hincks' illustrations. The operculum covers the greater part of the orifice, and is marked on the front surface. August 19, a tangle of this species mixed with an

hydroid was dredged in 20 fathoms. It answers in every respect to the one of August the first. The median avicularium is present on most of the cells, and some of them are of good size. Spines vary from one to three, and toward the upper part of the colony they are very long.

Scrupocellaria elliptica (Reuss).—A branch of this species about two centimetres high was taken from a stone brought up by a trawl from 30 to 50 fathoms. It is twice dichotomously branched; the vibracula are very long and serrated on one margin; the spines above the orifice vary greatly in length, and many are very long.

Caberea ellisii (Fleming).—This species is common. It was dredged in 30 to 50 fathoms, attached to a sponge and to *Terebratulina septentrionalis;* considerable quantities of it were also dredged in 20 fathoms attached to Balanus, stones, &c.

FAMILY: BICELLARIIDÆ.

Bugula sp.—One specimen about one inch in length was found on a mussel shell (*Mytilus edulis*) taken just below low water under a wharf at Canso. The zoarium is ascending, racemose, regularly dichotomously branched, the branches being rather narrow, and composed regularly of two series of zoœcia alternate with each other. The zoœcia are long, slightly tapering toward the base, and have at the upper part of the orifice five spines. The largest spine is at the upper outer corner; right in front of the larger spine is another one; a pair of spines, one on each side of the peristome, arise just below the other spines and almost or quite overlap each other; the lower inner spine sometimes absent; the orifice is very large, occupying almost the whole front of the zoœcium. Avicularia are entirely marginal in the form of bird's heads. They are pedunculated, and one is attached to the outer margin of each zoœcium considerably above the middle; they are stout, being about two-thirds as broad as long, and have both beaks hooked; they are attached by a disk-like base; the oœcia are almost globular, flattish at the lower end; they are raised, and attached by a narrow neck to the zoœcium below. On one polypide I counted twelve tentacles, on another thirteen. This species differs from *B. avicularia* in the form of the zoarium, the number of spines, in the fact that the avicularia are not elongated but quite stout, and in the number of tentacles.

FAMILY: MEMBRANIPORIDÆ.

Menbranipora pilosa (Linnæus).—This is found very commonly about Canso in depths of 10-15 fathoms. I found it on fronds of *Rhodymenia palmata, Ptilota plumosa,* and on the stipes of *Laminaria longicruris* washed up on the beach. It sometimes forms narrow patches one inch long and two to four cells wide on *Rhodymenia,* and in this case the basal spine is aborted, but the peristome is surrounded by about five rather short spines directed toward the centre of the peristome. Another peculiarity of this specimen is that on each side of the peristome there is an elliptical, transparent patch about one-fourth the diameter of the peristome. On *Lamiñaria* it forms encrusting masses, covering frequently the whole stipe. In these the basal spine is present but very short, and the marginal spines are often reduced to two lateral ones near the upper edge of the peristome. The peristome is very large, about one and one-half times the length of the tube below it. Specimens got on *Rhodymenia* and *Ptilota,* near Cranberry Light, in 15 fathoms, formed white encrusting masses, and had typical structure with very long basal spines.

Membranipora lineata (Linnæus).—Small patches were found quite frequently on *Laminaria* just below tide-mark. They are quite normal, except that some have as many as fourteen spines. A beautiful lace-like colony, two inches long, was found on a mussel shell. Every cell had a very prominent avicularium just below its orifice, which is raised greatly, and has its acute mandible never pointing down but always

obliquely upward. Generally only one pair of spines is present, and these are erect and situated near the top of the orifice.

FAMILY: CRIBRILINIDÆ

Cribrilina punctata (Hassall)?—I found two specimens, the identity of the first of which I am not sure. The first specimen was found encrusting a shell of *Litorina* which was inhabited by a hermit crab. The boundaries of the cells of the zoarium are not distinct; the whole front of the zoœcium is perforated with punctures of large size, giving it a reticulated appearance; the peristome is not greatly thickened on the lower edge, and bears no mucro; it has two spines on the upper margin that are directed inwards. The avicularia are generally absent, but an occasional one is seen on the edge of the peristome. The oœcia are large, covered with punctures, and contain ova of a beautiful pink colour. The second specimen was found on a stone at low-water mark. The two lateral avicularia are present on almost every cell. The spines on the peristome are rather irregular in number, some cells having none, some two. The lower border of the peristome is very slightly thickened, but the mucro is absent.

Cribrilina annulata (Fabricius).—Several very small patches were found on a stone between tide-marks, and a small patch 5 mm. in diameter, together with several other small patches, consisting of from one to three cells, was obtained from the frond of *Rhodymenia palmata* dredged in 20 fathoms, near the entrance to Canso harbour. All the specimens are of a pure white colour. In the larger patch on *Rhodymenia* the marginal zoœcia retain a pair of transparent spots laterally, also two above the orifice.

FAMILY: MYRIOZOIDÆ.

Schizoporella sinuosa (Busk).—A very old, encrusting mass was found on a stone taken by the trawler *Active*. The individuals can be distinguished by the naked eye. The orifice is orbicular, produced into an angle below. The wall is punctured, especially near the edge, where the punctures are large.

Schizoporella hyalina (Linnæus).—This species is very common about Canso. I have found it on *Laminaria longicruris, Fucus vesiculosus, Ascophyllum nodosum* and a red alga. In all cases it was found in very shallow water or just below tide-mark. The lateral denticles vary a good deal in size, sometimes being very conspicuous when the ventral sinus is deep, or very small when the ventral sinus is shallow.

FAMILYS ESCHARIDÆ.

Lepralia pallasiana (Moll).—A colony was found on a stone taken from under a wharf. There is no umbo, avicularia nor oœcia present; the reticulation is very pronounced and beautiful, the margin of the peristome is not greatly raised and its lower margin is more strongly curved than is indicated in Hincks' drawings.

Lepralia pertusa (Esper).—Specimens were found encrusting an ascidian dredged by the trawler *Active*. As I am not at all sure of the identity of this specimen, I shall give my notes in full. July 19: Zoarium encrusting of a white colour in several small patches. Zoœcia are very distinct, separated by raised lines, and form radiating rows; they are mostly rectangular, a few having a pointed base; a very distinct line of large pores at each lateral edge border the dividing, raised lines; these pores are separated by ridges passing inward radially for a short distance; the orifice is transversely elliptical with a distinct sinus on the lower side; just below the lower lip is a raised, conical or tubular structure with an opening circular above, but prolonged into an angle below; this structure does not come out straight but runs obliquely toward the orifice, no avicularia are present. Every feature is very distinct. July 27: Another specimen taken which is younger. It has an orange appearance and the walls

are translucent; the zoœcia are rather less regular in shape but are arranged in regular lines.

Porella concinna (Busk).—One specimen was got from a stone taken by the trawler *Active*. The wall is thickly punctured, the cells are not distinctly divided, the cell-wall is much raised about the orifice; the avicularia are generally present on the lower lip.

Escharoides rosacea (Busk).—A single specimen 5·6 mm. high divided into two lobes was taken by the trawler *Active* in about 30 to 50 fathoms; it was attached to a stone.

Mucronella sp.—The specimen was found on an ascidian taken by the trawler *Active*. It resembles closely *M. coccinea*. It is an encrusting form; the zoœcia are ovoid, narrowing below, quite flat, the outline of each is very distinct, the surface plainly granular; the orifice is almost terminal, it is rounded above and widest near the base; there are two lateral denticles near the base and a median, blunt denticle on the lower lip; two avicularia are present at the sides of the orifice, their lower edge is below the edge of the lower lip of the peristome; they point upward or inward or between the two positions; there are generally three spines present just above the orifice; the zoœcium is yellowish and dim toward the base. In a second specimen got from a stone taken by trawler *Active*, each zoœcium was punctured around the border very close to the raised, separating ridge. Avicularia are constantly present, only a few having a single avicularium.

FAMILY: CRISIIDÆ.

Crisia eburnea—(Linnæus).—Specimens of this were found on the base of red algæ dredged in 20 fathoms; two small tufts, 1 cm. high from base of stem of *Boltenia*; several branches 2·5 cm. high from stone obtained in Chedabucto Bay; from a hydroid dredged in 20 fathoms at the entrance to Canso harbour; one small branch found attached to *Lafœa dumosa* dredged in 20 fathoms near Canso harbour; a magnificent branch 2·5 cm. high found growing on *Rhodymenia palmata* dredged in 20 fathoms. The joints are always horn-coloured, branches generally do not arise from lowest zoœcium of the internodes but more frequently from the second, third, fourth or fifth. In one specimen oœcia are present. They are always at the base of the branch and are very ventricose with orifice not projecting nor tubular, but transversely narrow elliptical.

FAMILY: TUBULIPORIDÆ.

Tubulipora flabellaris (Fabricius).—Colonies were found on *Laminaria* dredged in 10 to 15 fathoms. The young colonies are fan-shaped, the adult are almost orbicular; there is no sign of lobation in either young or adult.

Idmonea atlantica (E. Forbes).—One colony 2·5 cm. long was got on a muddy bottom in 25-35 fathoms. The branching is fairly regularly dichotomous. There were no oœcia present. Another colony ·75 cm. high growing on *Lafœa dumosa* was got in the same locality.

Idmonea serpens, Linnæus.—Two small branches were found in an hydroid dredged in about 20 fathoms near the entrance to Canso harbour. Its colour is ivory white with no tinge of purple.

Entalophora clavata (Busk).—A small, erect colony less than 1 cm. high was found growing on an hydroid dredged at 20 fathoms. It sprang from the same base as a branch of *Idmonea*. It is unbranched but clavate at the end and resembles completely in form Hincks' illustration, Plate LXV., 8d. (Br. Mar. Polyzoa).

FAMILY: LICHENOPORIDÆ.

Lichenopora, sp.—I was unable to identify this specimen with any species described by Hincks in 'British Marine Polyzoa.' One small colony was taken off *Rhodymenia palmata* dredged in 20 fathoms near the entrance to Canso Harbour. The specimen is not more than 2 mm. in diameter. The zoarium is stipitate widening above into a shallow cup. There is a wide bordering lamina entirely free and curved up so as to make the edges of the cup. Zoœcia are arranged irregularly with the intervening cavities, also arranged irregularly; many of the orifices have long acuminate projections, some of which are bifid. The characteristic feature of the specimen is the form of the zoarium.

Lichenopora verrucaria (Fabricius).—This is a common species at Canso. I found it on *Laminaria* fronds washed up on the beach, on a blade of dead *Zostera* that came up in the dredge from 30 to 40 fathoms and several colonies on *Ptilota plumosa* dredged from 15 fathoms.

FAMILY: FLUSTRELLIDÆ.

Flustrella hispida (Fabricius).—This is very commonly found between tide marks coating the stems of *Ascophyllum nodosum.* It is always situated at the base of the stipe.

FAMILY: VESICULARIIDÆ.

Bowerbankia, sp.—Specimens were found growing on hybroids attached to mussel shells taken under wharfs. The zoœcia are in groups attached to both sides of a jointed stolon. The polypide has eight tentacles, the stomach is quite dark coloured, the gizzard conspicuous and many cells contain rounded, dark brown bodies.

Bowerbankia imbricata (Adams).—A small mass was found growing on the surface of *Membranipora lineata* attached to a mussel shell. The majority of the polypides have a large, red, oval larva in each, and this is the only distinct organ that can be seen. One had its tentacles projecting in a long, pointed mass, they seem to be more than ten, but I could not tell the exact number. I am not at all sure of the identity of this specimen.

FAMILY: PEDICELLINIDÆ.

Pedicellina cernua (Pallas).—Both the smooth and spiny variety of this species occurred on mussel shells taken under wharfs. Variety *glabra* is the more common, only one specimen of the spiny form was found and the spines on this were long and hair-like, and were not confined to the peduncle, but also cover the polypides. I counted fourteen tentacles in several individuals.

Pedicellina nutans, Dalyell.—This was found intermingled with Bowerbankia, sp. on a mussel shell got from under a wharf, and also mixed with *Pedicellina nutans* growing on *Membranipora lineata* got from a mussel shell.

Pedicellina gracilis, Sars.—One specimen of this species was found spread over an encrusting mass of *Membranipora lineata* on a mussel shell, which was got under a wharf, it was intermingled with *Pedicellina nutans,* and the cells of the two were about the same size. The peduncle was very long and slender, the expanded, cylindrical part at the base being hardly one-eighth of the whole peduncle, but in a few cases as much as one-fourth. In some individuals the peduncle expands above to form a capitate head which contracts suddenly at the polypide. The polypides are plainly gibbous on the sides. The stolon is jointed.

FAMILY: LOXOSOMIDÆ.

Loxosoma singulare, Keferstein.—Two specimens were found on *Schizoporella.* Both have two buds of different sizes on each side. The stalk is about one-half the length of the body, transversely marked, but the expanded disk below is hid from sight. It only varies from Hinck's description by having eight tentacles in one specimen. The number in the other could not be counted.

Unidentified.—A specimen was found on a stone taken by the trawler *Active.* It formed a very small, white, encrusting mass; the zoœcia are arranged in very irregular order and their boundaries are not distinct; the orifice is arched above and convex below, due to a tubercle arising just below the orifice; this tubercle has two lateral wing-like outgrowths below and in this way forms a crescent-shaped body on the front surface of the zoœcium; dim radial lines pass out from this to the margin; two spines arise from the upper side of the orifice. Many have globular oœcia above, and on these the spines are absent.

Another species was found on a stone and on the shell of Balanus taken by trawl of the *Active.* The zoarium is encrusting and of a greenish colour; zoœcia are of average size, very plainly marked off from one another and of irregular and various shapes, the whole surface is flat and covered with very large punctures giving it a reticulated appearance. The orifice is not terminal but at the upper end, not projecting, and almost perfectly orbicular; some have two lateral denticles near the lower edge; directly below the orifice is an avicularium with pointed mandible running nearly horizontal, or obliquely upward.

IX

NOTES ON THE FISHES OF CANSO.

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The following notes refer to specimens of fishes collected and determined at the Marine Biological Station during July and August in the two seasons of 1901 and 1902. In nomenclature and classification Drs. Jordan and Evermann's 'Fishes of North and Middle America' has provided the authority followed. The specimens, it may be added, were collected mainly during the trips of the fishing steamer *Active*, operated by the Messrs. Whitman, of Canso, or were obtained along the shore, or in shallow water about the wharfs of the harbour, or in the areas thickly overgrown with eel-grass, adjacent to the laboratory. I visited several times each week the traps set for mackerel and squid in water about six fathoms in depth quite close to the land. The *Active* furnished most specimens, secured during her daily fishing trips, a few miles from the harbour, where trawls of hooks were set for cod and haddock. For about a month during 1901 the beam-trawl was used in Chedabucto Bay at a depth of 18 to 20 fathoms, with most noteworthy success. A few fish were kindly brought by some of the local fishermen from the 'Banks' and by some of the deep-sea fishermen who fish in small boats with handlines or with long lines of hooks known as 'trawls.' I cannot refrain from making special reference to the willing aid of Mr. C. H. Whitman, who most kindly compiled statistics regarding the local 'takes' of certain fishes of which I have made use, as well as for much other assistance during the whole course of the work of collecting specimens.

FAMILY: GALEIDÆ.

1. *Prionace glauca* (Linnæus).—This species, called in the locality of Canso the 'Blue Dog,' is very common in the adjacent waters, and is reported by the cod fishermen to be extremely plentiful on the 'Banks.' Two specimens which I measured were 1,423 mm. and 1,437 mm. respectively from the tip of the snout to the concavity of the tail. In one there were three gills upon one side atrophied. They are stated to die upon the trawl hook more quickly than the cod or the picked dog-fish (*Squalus acanthias*), so that they are rarely brought on deck alive. The fishermen think that when they take the hook they are unable to close the mouth, and thus drown. I have seen one come to the surface when out fishing with the hook trawl, and after it had snapped off a codfish from the trawl it would circle round, with its dorsal fin exposed, and rapidly gather up the fragments, an occurrence which I am informed is very common on the fishing grounds. An examination of the stomach showed a few shrimps only, and in the longitudinal spiral valve were many specimens of a tape-worm.

FAMILY: SQUALIDÆ.

2. *Squalus acanthias,* Linnæus.—This is an extremely common species, and often a great nuisance to the fishermen fishing with trawls of baited hooks. I have known gear with 700 hooks to have 690 of these dog-fish upon it. No use is generally made of these fish ; they are difficult to release from the hooks, and they generally snap off

the snood; they are regarded with much disfavour. As Professor Prince pointed out in his report on the 'Dogfish Pest in Canada' (Fisheries Report, Department of Marine and Fisheries, Ottawa, 1903), this species has proved a most destructive enemy to the sea fishermen's pursuits, and his recommendations to the government favouring reduction works for converting dogfish into fertilizer, oil, glue, &c., are now being carried out.

FAMILY: RAIIDÆ.

3. *Raia ocellata,* Mitchill.—A most common species at Canso, though some of the specimens which I examined may belong to the allied species *R. erinacea.* I found it difficult to decide finally in the case of some examples. They were all taken in trapnets set for mackerel, close along the shore. I give the following details in regard to four specimens:—

Length.	Number of Teeth.	Sex	Ocelli.
700 mm.	78 85	Male	Not distinct.
689 mm.	69 77	Female	Absent.
715 mm.	91 90	"	Present.
610 mm.	71 73	Male	Absent.

The last-named specimen exhibited several rows of spines along the tail, which would indicate that it is *R. ocellata*; but in it and in the second specimen the number of teeth present is intermediate between the diagnostic dentition of the two species. In the two male specimens the double row of erectile spines points inward to the middle line rather than backward. In none of those in which ocelli are present is there any central dark spot. Their food was found to be dollar fish (*Poronotus triacanthus*), the cunner (*Tautogolabrus adspersus*) and squid, remains of which occurred in the contents of the stomach.

4. *Raia lævis* (Mitchell).—This species is frequently captured by the cod fishermen on their deep-sea trawls of hooks. The only specimen minutely examined by me was 1,075 mm. long. In colour it was light-brown dorsally, with scattered dull black spots. There were two large ocelli surrounded by a black ring; ventrally, it exhibited small black spots; some of them were arranged in two rows.

5. *Raia radiata,* Donovan.—This skate or ray is usually called the Starry Ray, and it is the most common species taken on the local cod-trawls. Hence Drs. Jordan and Evermann are not perfectly accurate, so far as eastern Nova Scotia is concerned, in saying that this species is not common on the Atlantic coast. I have seen several dozens taken in about three hours by one dory. Nor are the American authorities accurate as to the size, as I have seen half a dozen amongst an afternoon's catch on board a dory each of which exceeded three feet in length. Two that I measured accurately were 994 mm. and 1,126 mm. long, the former being a female and the latter a male. The fishermen informed me that they secure very frequently specimens of the dimensions just specified. On two small specimens (145 mm. long) taken in the dredge the lateral spines on the tail were quite rudimentary. A large spine was present just

behind the spiracle in the specimens examined. In one large specimen I noticed a row of transverse black lines on each side dorsally and running backward almost parallel, but on the tail approaching and becoming obscure.

Of the Teleosteans, or bony fishes, specimens embracing fifty-one species passed under my examination, and in regard to these the following notes were prepared:—

FAMILY: ANGUILLIDÆ.

1. *Anguilla chrysypa,* Rafinesque.—Specimens of the common eel are plentiful in the long eel-grass inshore and in shallow water. They are caught in traps and eel-pots. The young, less than 10 cm. in length, are also found in shallow water near the shore.

FAMILY: CLUPEIDÆ.

2. *Clupea harengus* (Linnæus).—The common herring is not abundant and is not commercially important. A few are taken from the trap-nets, but never more than a barrel or two. They varied in length from 189 mm. to 235 mm.

3. *Pomolobus pseudoharengus* (Wilson).—This species, called locally the Alewife or Gaspereau is taken in small quantities in the trap-nets, but is commercially unimportant.

FAMILY: SALMONIDÆ.

4. *Salmo salar* (Linnæus.)—Young specimens about 230 or 250 mm. in length are commonly taken in the early summer, and adults are caught in spring and early summer.

FAMILY: ARGENTIDÆ.

5. *Osmerus mordax* (Mitchell)—The smelt is common, though not found in the vast quantities which occur in the more northern estuaries. It is caught by hook and line from the wharfs, and in the trap-nets. Owing to the limited quantities taken, none are shipped from Canso to the markets as a rule.

FAMILY: PŒCILIIDÆ.

6. *Fundulus heteroclitus* (Linnæus).—The common killifish is plentiful in brackish ponds near the beach at Canso.

FAMILY: SCOMBRESOCIDÆ.

7. *Scombresox saurus* (Walbaum).—Large schools of this species can often be seen skipping over the water trying to escape from the voracious pollack. A few are caught in the trap-nets, and on one occasion a specimen was washed on board the tug during one of our scientific trips in the bay.

FAMILY: GASTEROSTEIDÆ.

8. *Pygosteus pungitius* (Linnæus).—In one pond near the seashore this small fish is very common; but, curiously enough, it is entirely absent from another pond quite similar in its physical features, and practically adjoining.

9. *Gasterosteus bispinosus* (Walbaum).—This species is abundant in tidal pools and in ponds near the beach. They seem to be of two sizes, with no intermediate links. Those of larger size are 53-60 mm. in length, and are confined to the tidal pools, while

the smaller specimens, 20-26 mm., are found both in the tidal pools and in the brackish water ponds, and in both sizes the genital organs were found to be mature. I made accurate measurements of seven examples, and found that, in three of them, the first dorsal spine does not reach the second, in one the tip just touches the base of the second, and in three it projected beyond the base of the second. The ratio of length to height in the seven are 4·3, 4·1, 3·8, 4·2, 4·3 and 4·9, hence the distinction which has been drawn between *G. spinosus* and *G. aculeatus* does not hold in the case of the Canso specimens. I made some endeavour to decide if other peculiarities could be correlated with the red throat and red fin membrane which many exhibited. Out of 245 specimens collected from the pond, 16 were distinctly red-throated, and 8 red-throated specimens examined were found to be males with active spermatozoa in the testes. Out of 10 with pale throat 5 were females and 5 proved to be males showing active spermatozoa.

10. *Apeltes quadracus* (Mitchell).—This species was common in a brackish pond near the beach. The head I found to be contained 4·3 times in length, and the depth 4·3-4·8 in the length. The anal spine does not come under the third dorsal ray, but under the fourth, fifth or even under the seventh. In a large number the ventral fins have orange-red membranes, and sometimes the membrane of the dorsal and the anal spines are red. All with coloured membranes I ascertained to be males, and seven specimens not so tinted were females. I could detect no external marks of difference in the colouration of males and females excepting the red membranes. The dorsal spines are bent irregularly to the right and left, and in about one-third of the examples obtained the dorsal spines were four in number.

FAMILY: SCOMBRIDÆ.

11. *Scomber scombrus* (Linnæus).—Of this valuable food-fish variable quantities are captured by gill-nets and traps. They are usually shipped fresh to the Canadian markets, the fishermen receiving two to ten cents a piece for them, and the fishing season lasts from May to November. In one season recently over 250,000 mackerel were taken by Canso fishermen.

12. *Thynnus thynnus* (Linnæus).—The mackerel traps often capture specimens of this large species about the end of July and in the month of August. They are often called by the erroneous names, mackerel shark or horse-mackerel, the former being really the porbeagle (*Lamna*) and the latter the scad (*Trachurus*). The name tunny is correct and most appropriate, and in the Mediterranean sea it is one of the principal fisheries pursued, while in Japan it is an esteemed food-fish, raw, salted, smoked and canned in oil. At Canso they are occasionally captured, but one trap in a few weeks took over forty. All were liberated, as there is no market for them. They are often seen swimming near the surface of the sea.

FAMILY: AMMODYTIDÆ.

13. *Ammodytes americanus* (DeKay).—This species was found only at one point at Canso. On a sandy beach at the entrance of a cove connected with Canso harbour they occurred very numerously at low tide. The drag seine used at this place on being hauled in quickly captured many hundreds in a short time. They were often found stranded on the shore as the tide went out, and were also dug out of the sand at a depth of six inches. They appeared to be of two sizes, without intervening stages. Twenty-five of the larger ranged from 157 mm. to 184 mm. in length, and ninety of the smaller type were found to measure 60 mm. to 89 mm. in length. The stomach was often empty; but when filled contained small crustacea, some of which were not secured in the immediate locality, and did not appear to occur locally.

FAMILY: XIPHIIDÆ.

14. *Xiphias gladius* (Linnæus).—This species while not one of the common species captured at Canso, is at times taken in the trap-nets. One was secured in that way in 1901, and one in 1902 came to my notice. A demand has arisen for these fish commercially, and they have a high reputation in the United States markets, and being of large size (200 to 400 pounds being a frequent range of their weight) the fishery might become a remunerative one were it developed.

FAMILY: CARANGIDÆ.

15. *Decapterus macarellus* (Cuv. and Valenc).—Two specimens of this species were caught in the Chedabucto Bay trap-nets. They were wholly unfamiliar to the fishermen, and are apparently rarely seen at Canso.

16. *Trachurops crumenophthalmus* (Bloch)?—Two specimens were taken in the trap-nets by local fishermen, to whom the fish was unknown before. The specimens were found to differ from the description of Drs. Jordan and Evermann in two respects,—there are no scales on the cheeks, and, along the side, a bright golden-yellow band passes longitudinally below the lateral line anteriorly; but about midway it crosses and then passes back above the lateral line.

FAMILY: CENTROLOPHIDÆ.

17. *Palinurichthys perciformis* (Mitchell).—The fishermen call this species the 'Rudder fish,' and are familiar with it, as they state that it follows their sailing vessels into port from the 'Banks.' One specimen was taken by hook at the Canso wharf.

FAMILY: STROMATEIDÆ.

18. *Poronotus triacanthus* (Peck).—This small silvery fish is fairly common, and is frequently captured in the trap-nets.

FAMILY: SERRANIDÆ.

19. *Roccus lineatus* (Bloch).—Young specimens 170 mm. long of this fine fish, which when adult may measure 3 to 5 feet in length and weigh from 20 to 100 pounds, are frequently caught by boys with hook when fishing for smelt.

FAMILY: LABRIDÆ.

20. *Tautogolabrus aaspersus* (Walbaum).—An excessively abundant fish about the wharfs. It is very variable in size and colour, and is popularly known as the perch or cunner.

FAMILY: BALISTIDÆ.

21. *Balistes carolinensis* (Gmelin).—One specimen of this remarkable File-fish was brought in by the deep-set fishermen, who stated that it was 'gaffed' on Banquereau Bank, about fifty miles southeast of Canso. It was seen near the surface swimming around a floating buoy. Its captors had never seen one before, and it may be added that while the members of the family are abundant in tropical seas they become very scarce in higher latitudes.

FAMILY: MOLIDÆ.

22. *Mola mola* (Linnæus).—The sun-fish, as it is called all over the Atlantic waters of Europe and this continent, is not uncommon at Canso and out on the 'Banks.' Specimens even come close to the beach, and one was driven ashore by the fishermen with oars and gaffs, and was brought to the station. Another example was also obtained, and the measurements of each respectively were 1,480 mm. long and 1,780 mm., vertically from the tip of the dorsal to the tip of the anal fin, in the first, and 1,790 mm. long and 2,020 mm. vertical measure, in the second. The stomach of one was empty, while in the other were found two squid.

FAMILY: SCORPÆNIDÆ.

23. *Sebastes marinus* (Linnæus).—A few specimens of this fish called locally 'Red Perch' or 'Gale fish,' or more widely the 'Norway haddock,' are taken on every trawl of hooks, but no use is made of them. They frequent a soft bottom at the base of the slope from shallow to deep water at about 60 fathoms. I found that neither the pectoral nor ventral fins are long enough to reach the anus.

FAMILY: COTTIDÆ.

24. *Triglops pingeli* (Reinhardt).—A specimen swept into the beam-trawl net at 18 fathoms depths in Chedabucto Bay was 78 mm.; and in several respects it differed from the description given by Drs. Jordan and Evermann. The series of spines along the base of the dorsal fin is continued to the caudal fin; but from the middle of the second dorsal fin the spines are small and not obvious. Dorsally it is light greenish-brown, mottled with a light reddish shade of the same colour. There are four dark saddles across the back; an interrupted black line runs along the side; there is no ocellus on the anterior dorsal fin. Each of the dorsal fins exhibits three black lines, while the pectoral fin has four dark bars and the anal fin is white. A distinct dark line runs below the eye on each side of the head.

25. *Myoxocephalus grœnlandicus* (Cuv. and Valenc).—This species is exceedingly common in shallow water, and shows great variation in colour. It ranges in length from 130 to 170 mm.

26. *Myoxocephalus octodecimspinosus* (Mitchill).—Several specimens were taken in the beam-trawl net in 18 fathoms of water on a sandy bottom in Chedabucto Bay. In one example, 201 mm. long, the soft dorsal fin had a short anterior spine; but possibly this feature was not normal, as in two smaller specimens it was absent. In the same large specimen the preopercular spine does not extend so far as the opercular spine; but this does not apply to the two smaller examples.

27. *Hemitripterus americanus* (Gmelin)—This is a very common fish at Canso, and as a rule called the 'Sculpin.' It occurs at depths of a few feet down to 50 or 60 fathoms, and varies most remarkably in colour; some are bright red, others dark brown, and there are intermediate shades. The brilliant-red specimens generally occur in deep water; but the dark-brown type occurs at all depths. Large specimens are taken, the largest being no less than 511 mm. long. They are used as bait in the lobster traps with other rejected or 'offal' fish.

FAMILY: AGONIDÆ.

28. *Aspidophoroides monopterygius* (Bloch).—The beam-trawl net secured several specimens in Chedabucto Bay at a depth of about 18 fathoms.

FAMILY: CYCLOPTERIDÆ.

29. *Cyclopterus lumpus* (Linnæus).—This fish, generally known as the lumpfish, lumpsucker, or in Scotland the 'paidle,' is plentiful at Canso in the spring; but much scarcer in summer. I examined one specimen caught by a fisherman on his baited hook while fishing for pollack. The colour appears to fade very quickly from the slimy skin after death.

FAMILY: BLENNIIDÆ.

30. *Pholis gunnellus* (Linnæus).—This eel-like familiar fish, often called the Gunnel or Butterfish, is very common under stones at low water, and eludes capture by reason of its exceedingly slimy, slippery integument.

31. *Stichæus punctatus* (Fabricius).—One specimen of this peculiar blenny was found in the beam-trawl net when fishing in 18 fathoms of water in Chedabucto Bay on a sandy bottom. Another was obtained in a moribund condition under a wharf. The markings differ very much from the description of Drs. Jordan and Evermann. There is no tinge of scarlet; but the colour is light-brown above, whitish-yellow below, while black blotches occur dorsally, and eight or nine large irregular brownish blotches on the sides. There are twelve black spots on the anal fin. The blotches on the side are somewhat indistinct in one of the specimens.

32. *Ulvaria subbifurcata* (Strong).—Four specimens of this species were obtained. One was found under some stones on the beach, when looking for gunnel or butterfish, while two were brought up in the dredge in 6 to 10 fathoms of water, and the fourth was taken in the beam-trawl net in the bay in 30 fathoms of water. It would appear, therefore, not to be wholly a deep-water fish, and I may add that there can be no doubt as to my identification of the specimens.

FAMILY: CRYPTACANTHODIDÆ.

33. *Cryptacanthodes maculatus* (Storer).—This rather uncommon fish is taken on the hooks of the haddock-trawls at about 20 fathoms depth. It is often called the Lamper-eel, in common with *Zoarces* the viviparous blenny. All the specimens in my hands were dark in colour; the lateral line was distinct, showing about 140 pores, and the colouring is lighter along this line.

FAMILY: ANARHICHADIDÆ.

34. *Anarhichas latifrons* (Steenstrup and Hallgrimsson).—One very large specimen of the wolf-fish was taken on the trawl of the steamer *Active* in about 50 fathoms. I learned that not more than one or two specimens are secured in a season, so that it is not a common fish. Its length was 1,166 mm., or including the caudal fin to its final margin, 1,240 mm. The shape of the fish differed very much from that given by Drs. Jordan and Evermann, as the abdomen was far more prominent, the vertical depth being contained three times in the length. The mouth for so large a fish seemed small, and the vomerine teeth extended within one centimetre of the posterior palatines. The American authorities referred to are certainly in error in stating as a generic character the presence of an air-bladder. There is no sign of such an organ in this species or in the Sea-cat, *A. lupus*. The dorsal fin is continuous with the caudal fin; but becomes very much narrowed as it approaches the caudal. This fish is of a dark-brown chocolate colour, obscurely mottled. Four sea-urchins, 45 to 60 mm. in diameter, were found intact in the stomach, except that the spines were detached.

35. *Anarhichas lupus* (Linnæus).—This species is common at Canso, and almost every trawl of hooks brings up a few. The local fishermen call it 'Catfish,' as they do

in Britain, and they are loud in its praises as an edible fish, though it is treated as 'offal' fish. I took from the stomach gastropod and lamellibranch shells, hermit crabs, sea-urchins, and the much branched *Astrophyton.*

36. *Anarhichas minor* (Olafsen).—Occasional specimens, differing from the two foregoing species, are occasionally brought in by the fishermen, and appear to belong to this species. Like *A. latifrons* this is usually regarded as a purely Arctic wolf-fish.

FAMILY: ZOARCIDÆ.

37. *Zoarces anguillaris* (Beck).—This species appears to be common at about 20 fathoms depth, and is constantly caught by the trawl hooks or in the beam-trawl net. The usual name for it at Canso is Rock-eel or Lamper-eel. There are great variations in the relative dimensions of the head, pectoral fin and abdomen, and in the thickness of the lips. I noticed that the first ray of the dorsal fin is generally behind the line of the preopercle, and not above it.

38. *Lycodes*, sp.—Three specimens were taken on the trawl-hooks of the steamer *Active* at a depth of about 50 fathoms where the bottom is sandy. The fishermen declare that it is sometimes taken on the 'Banks;' but they appear to have no popular name for it. One man called it the 'Laughing Jack.' It seems to correspond with no species described by Drs. Jordan and Evermann, and I therefore give my notes on the specimens in detail:—

	Specimen No. 1.	Specimen No. 2.
Length	662 mm.	656 mm.
Head	166 mm.	160 mm.
Depth	87 mm.	90 mm.
Width of eye	22 mm.	18 mm.
Interorbital space	26 mm.	26 mm.
Snout	57 mm.	60 mm.
Pectoral fin	94 mm.	94 mm.
Ventral fin	14 mm.	15 mm.
Dorsal fin	....	96 rays
Anal fin	....	69 rays
Pectoral fin	18 rays	18 rays
Upper jaw, length	....	84 mm.
Lower jaw, length	....	54 mm.
Base of ventral to anus	....	166 mm.
Depth at anus	....	75 mm.
Distance between nostrils	....	30 mm.
Distance from eye to nostril	....	38 mm.
Highest dorsal ray	....	39 mm.
Highest anal ray	....	30 mm.

The head is very wide and flat, while the body is compressed and tapers backward to a point. The jaws have very wide flaps, which on the upper jaw project very much. A fold of skin on the chin runs parallel with the edge of the lower mandible and ends in a free laterally compressed flap. The lower jaw is included. The teeth are all conical, and are found on the upper and lower jaws, palatines, and vomer. In the upper jaw there is one row supported at the front by two or three small teeth on a posterior row; the vomerine teeth form a small transverse oval patch; the palatines form a single row on each side diverging posteriorly; in the lower jaw there are three rows for a short distance anteriorly and one row follows posteriorly; the row of maxillary teeth is 35 mm. long, palatines 29 mm., vomerines 9 mm. × 4 mm., mandibular 55 mm. long. The dorsal fin commences about 2 cm. behind the pectoral; the dorsal and anal unite around the caudal; both are highest at the anterior, tapering posteriorly; the ventral fins are conical, almost teat-like. Scales are present on the sides of the body, beginning a little behind the pectoral fin, and are round, cycloid, the

largest being about 1 mm. in diameter; they are imbedded in skin, the spaces between them being about two diameters. The dorsal and anal fin are scaly to the free margin behind, but the distal part is naked anteriorly. The head, part of the nape, sides of body for 2 cm. behind the pectorals, the abdomen, pectoral and pelvic fins are scaleless. The ground colour is a greenish-yellow except on the chin, throat and pectoral fins, which are whitish, the latter becoming dusky toward the tips. The sides and top of the head are reticulated with black, passing just in front of the top of the gill-slit; over the top of the head from side to side is a light, conspicuous band of the ground colour bounded at the edges by a wavy, black line; about nine wide, black, transverse bands pass across the sides, and are extended into the dorsal fin, where they are lost; these black bands become less distinct posteriorly, and do not extend to the ventral surface; each band consists of a reticulation of black on a green back-ground. It is quite unlike the reticulations of *L. reticulatus,* as the black is not in narrow lines but in bands of 5 to 10 mm. in width. The dorsal fin is edged with darker, the anal fin has scattered shades of dusky most marked posteriorly. There are indications of the median lateral line on the last 150 mm. of the tail.

FAMILY: GADIDÆ.

39. *Pollachius virens* (Linnæus).—This is one of the most abundant food-fishes at Canso, 500,000 pounds being the annual catch. It is captured usually with hook and line in the surface waters from June to December. A few, however, are brought up on the hooks of cod-trawls from 30 to 50 fathoms. On being brought to the wharf, the head is removed and the backbone excised. They are then salted and shipped to the West Indies. The fishermen receive from one-half to one cent per pound for their pollack.

40. *Urophycis tenuis* (Mitchill).—This species of hake, commonly called 'Squirrel hake' by the fishermen, is captured occasionally on the cod-trawl hooks on muddy bottoms. One specimen carefully examined by me varied considerably from the description of Drs. Jordan and Evermann, and I therefore detail the measurements: Length, 865 mm.; depth, 215 mm.; orbit, 36 mm.; snout, 63 mm.; inter-orbital space, 58 mm.; length of pectoral fin, 144 mm.; head, 235 mm.; length of filamentous dorsal ray filament, 85 mm.; rays of dorsal fin numbered 11, 54, the rays of the anal fin 50, of the pectoral fin 15, of the ventral fin 4. Twelve rows of scales occurred between the lateral line and the anterior dorsal fin; the number of scales along the lateral line is 130. The head as shown by the examination of several other specimens was found to be contained less than four times in the length, and the depth to be contained less than five times in the length. I may add that the term 'Squirrel hake' may be applied to any small hake.

41. *Enchelyopus cimbrius* (Linnæus).—Two specimens were secured by the beam-trawl in 30 fathoms of water in Chedabucto Bay.

42. *Gadus callarias* (Linnæus).—The cod is of course a supremely important fish of Canada. The fishing season extends throughout the year, and about 3,566,000 pounds of this fine food-fish, for which the fishermen receive from $\frac{3}{4}$ to 2 cents per pound, are taken annually. 1,000,000 pounds are salted and dried, 1,000,000 are salted, 1,000,000 pounds are shipped fresh packed in ice, and 500,000 pounds are shipped fresh frozen. The fresh fish supplies the market for Canada, and the salted is disposed of in Canada and the West Indies.

43. *Melanogrammus æglefinus* (Linnæus).—About 3,000,000 pounds of this fish are taken annually at Canso. 400,000 pounds are smoked and 25,000 pounds are salted; 25,000 pounds are salted and dried, 2,000,000 pounds are shipped fresh packed in ice, and 550,000 pounds are shipped fresh frozen. The fresh and smoked are consumed in Canada, the salted in Canada and the West Indies and the dried in the West Indies.

Fishermen receive one-half to two and a half cents per pound. They are caught throughout the year.

FAMILY: PLEURONECTIDÆ.

44. *Hippoglossus hippoglossus* (Linnæus).—This is a very important food-fish. The size varies from a few pounds to two hundred or even more dressed. They are caught with hook and line and on the trawls. Those with the lower surface white are considered much better than those with a duller colour, and bring a much better price. 300,000 pounds are caught annually, which is shipped fresh to the Canadian market. Fishermen receive from 1 to 10 cents a pound. They are caught throughout the year.

45. *Reinhardtius hippoglossoides* (Walbaum).—This fish is not uncommon at Canso. It is taken on the trawl on muddy bottom in about 50 fathoms or deeper. It is here called the 'Turbot,' and is considered good eating. The anal and dorsal fins are scaled, and the number of canines in upper jaw varies, one having two on right side and three on left; another has two on right side and one on left side.

46. *Hippoglossoides platessoides* (Fabricius).—This is a very common fish on the trawls, and is only occasionally marketed. Very many young specimens from 4 or 5 cm. to 25 cm. long were taken in the beam-trawl at 20 fathoms in Chedabucto Bay. The young specimens have characteristic markings; along the dorsal margin are three distinct large, black, round ocelli, and on the ventral margin are four ocelli; other smaller fainter spots are also seen on the margins.

47. *Limanda ferruginea* (Storer).—A few specimens were got in the beam-trawls from 20 fathoms in Chedabucto Bay.

48. *Pseudopleuronectes americanus* (Walbaum).—This is the common flat fish of shallow water. It is seen under wharfs, in eel-grass, and a few were captured every day in the trap-nets. Many were taken by beam-trawl in 20 fathoms.

49. *Glyptocephalus cynoglossus* (Linnæus).—A few of these were got by the beam-trawl in Chedabucto Bay. The fishermen call it the 'Lemon Sole' or the 'Fluke.'

50. *Lophopsetta maculata* (Mitchell).—One specimen 230 mm. long was got from a thap-net and two or three were got by the beam-trawl in Chedabucto Bay.

FAMILY: LOPHIIDÆ.

51. *Lophius piscatorius* (Linnæus).—This fish is obtained very commonly on the hooks of the long trawls in deep water and at moderate depths.

X

PRELIMINARY REPORT ON THE TREMATODES OF CANADIAN MARINE FISHES.

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The worms that live parasitically upon the surfaces or in the cavities or tissues of our fishes may be distributed into six groups :—

1. Turbellaria.
2. Trematoda (Sucker worms).
3. Cestoda (Tape worms).
4. Nematoda (Thread worms).
5. Acanthocephala (Hook-headed worms).
6. Hirudinea (Leeches).

Excepting the first, each of these groups is represented by numerous different kinds as will be indicated in this brief account by the enumeration of the species of Trematodes hitherto observed at the biological station, with an appended list of their hosts. The Trematodes are commonly divided into (1) Ectoparasitic Trematodes, or those that live on the skin or gills, and (2) Endoparasitic Trematodes, or those that occupy some internal organ. The first are generally the more active, often possessing such special sense organs as eyes; are well adapted, by flatness of form in the larger species, and especially by the presence of suckers or hooks, to their habit of clinging to the surfaces of their hosts; are most closely affiliated by organization with their nearest relatives among free-living worms; and develop from eggs by a direct and gradual process of growth. The second are generally more quiescent, having no special sense organs; are more completely adapted to life in an internal organ; possess typically two suckers (sometime only one) and no hooks; and develop primarily from eggs, but by a long, often complex series of transformations. The parasite during these transformations lives at one stage in such an animal as a snail (intermediate host), and at a later stage in a fish (final host) which has eaten the snail and in which the worm now comes to full development and produces eggs.

The life-histories of the species catalogued below are not known to me and are matters for future research, but from what is known of others we may anticipate that the eggs of an ectoparasitic Trematode are deposited where it lives, on the gills or skin of a fish. The embryos develop in the egg-shells or capsules which finally burst, and then the young animals either remain on the same host or swim about for a short time. In the latter case they may spread to new hosts, especially if a school of fishes is in proximity, and settle down to the mode of life of their ancestors.

With the endoparasitic Trematodes it is different. Each worm retains in its long uterus an enormous number of eggs, only the first-formed or oldest of which are from time to time deposited in the organ of the host occupied by the worm (intestine, gall-bladder, urinary-bladder, &c., of a fish) and make their way out with the excrements. When the eggs reach the sea water their contained embryos are already advanced in organization, being provided with locomotory cilia and eye-spots; and, upon bursting the shells, are capable of spending a brief existence as free-swimming larvæ (Mir-

acidia). During this time they must find suitable hosts (snails, annelids, crabs, &c.), into the soft parts of which they penetrate. Here they remain immature, but their locomotory and sense organs degenerate, and they become so far transformed and so entirely different from either the free-living miracidium or the mature adult as to be completely unrecognizable, in which case the specific identity can only be made out by finding intermediate stages. It may also happen that the larva in the snail (called a sporocyst) does not transform directly or slowly into the adult form, but by a kind of internal budding produces clusters of cells that develop into new individuals, the old individuals becoming disintegrated and destroyed. The primary intermediate host may, in some cases, serve as food to a secondary intermediate host, which in its turn falls prey to the final host, in each case the parasite suffering a change of environment. Sooner or later—but always in the definitive host (a fish)—the parasite reaches its final development, becoming sexually mature and producing eggs.

The list of species studied at the Marine Biological Station in the course of my investigations is as follows—

I. Turbellaria.

1. *Micropharynx parasitica* Jägerskiöld.
   (=*Pseudocotyle fragile* Olsson). On the skin of the barn-door skate, *Raja lævis* Mit.

II. Ectoparasitic Trematodes.

1. *Tristomum molae,* Blanchard. On the skin of the sun-fish (Mola mola L.).
2. *Tristomum coccineum,* Cuvier. On the gills of the sword-fish (Xiphias gladius L.).
3. *Epibdella hippoglossi,* O. F. Müller. Skin of halibut (Hippoglossus hippoglossus L.).
4. *Acanthocotyle verrilli,* Goto. Skin of starry-ray (Raja radiata Don.).
5. *Pseudocotyle apiculatum,* Olsson. Skin of dog-fish (Squalus acanthias, L.).
6. *Udonella caligorum,* Johnston. Attached to tails of specimens of *Caligus* which are themselves parasitic crustacea on the skin of the cod-fish (Gadus callarias L.).
7. *Octocotyle scombri,* Kuhn. Gills of mackerel (Scomber scombrus L.).
8. *Dactylocotyle denticulatum,* Olsson. Gills of pollack (Pollachus virens, L.).
9. *Dactylocotyle phycidis,* Parona et Perugia. Gills of hake (Phycis chuss Walb.).
10. *Anthocotyle merlucii,* van Beneden et Hesse. Gills of silver hake (Merluccius bilinearis Mit.).
11. *Onchocotyle abbreviata,* Olsson. Gills of dog-fish (Squalus acanthias, L.).

III. Endoparasitic Trematodes.

1. *Distomum veliporum,* Creplin. In the oesophagus, stomach, and intestine of the barn-door skate (Raja laevis Mit.).
2. *Derogenes varicus*, O. F. Müller. Mouth, oesophagus, stomach of—
   Salmon (Salmo salar L.).
   Cod (Gadus callarias L.).
   Haddock (Melanogrammus aeglefinus L.).
   Pollack (Pollachius virens L.).
   Herring (Clupea harengus L.).
   Smelt (Osmerus mordax, Mit.).
   Rose-fish (Sebastes marinus L.).

Eel (Anguilla anguilla L.).
Wry-mouth (Cryptacanthodes maculatus Storer).
Sculpin (Acanthocottus scorpius, L.).
Sea raven (Hemitripterus Americanus Gmelin).
Angler (Lophius piscatorius, L.).
Halibut (Hippoglossus hippoglossus L.).
Sand dab (Limanda ferruginea Storer).
Greenland turbot (Platysomatichthys hippoglossoides Walb.)
Rough dab (Hippoglossoides platessoides Fab.).

3. *Hemiurus appendiculatus,* Rudolphi. Oesophagus and stomach of—
Salmon (Salmo salar L.).
Smelt (Osmerus mordax, Mit.).
Herring (Clupea harengus L.).
Cod (Gadus callarias L.).
Pollack (Pollachius virens, L.).
Sand lance (Ammodytes tobianus L.).
Eel (Anguilla anguilla L.).
Sculpin (Acanthocottus scorpius, L.).
Halibut (Hippoglossus hippoglossus L.).
Greenland turbot (Platysomatichthys hippoglossoides Walb.)

4. *Lecithaster bothryophorus,* Olsson. (=*Apoblema mollissimum* Levinson). Intestine of—
Salmon (Salmo salar L.).
Herring (Clupea harengus L.).

5. *Distomum simplex,* Rudolphi. Intestine of—
Salmon (Salmo salar L.).
Rose-fish (Sebastes marinus L.).
Stickleback (Gasterosteus aculeatus L.).
Hake (Phycis chuss Walb.).
Mackerel (Scomber scombrus L.).
Sculpin (Acanthocottus scorpius, L.).

6. *Stephanochasmus sobrinus,* Levinsen. Rectum of—
Sea raven (Hemitripterus Americanus Gmelin).
Wry-mouth (Crypstacanthodes maculatus Storer).
Lycodes sp.

7. *Stephanochasmus hystrix,* Desjardins. Encysted on fins of Winter flounder (Pseudopleuronectes americanus, Walb.).

8. *Deropristi inflata,* Molin. Small intestine of Eel (Anguilla, anguilla L.).

9. *Distomum rachion,* Cobbold. Intestine of Haddock (Melanogrammus aeglefinus, L.).

10. *Distomum furcigerum,* Olsson. Stomach and intestine of—
Winter flounder (Pseudopleuronectes americanus, Walb.).
Greenland turbot (Platysomatichthys hippoglossoides, Walb.).
Rough dab (Hippoglossoides platessoides, Fabr.).
Wry-mouth (Cryptacanthodes maculatus, Storer).

11. *Lepidophyllum steenstrupi,* Odhner. Urinary bladder of—
Wolf-fish (Anarrhicus lupus, L.).
Eel-pout (Zoarces anguillaris, Peck).

12. *Distomum incisum,* Rudolphi (= Distomum fellis, Olsson). Gall-bladder of—Wolf-fish (Anarrhicus lupus, L.).

13. *Distomum fragile,* Linton. Intestine of Sun-fish (Mola mola, L.).

14. *Accacoelium contortum,* Rud. Gills of Sun-fish (Mola mola, L.).

15. *Accacoelium macrocotyle,* Diesing?. Intestine of Sun-fish (Mola mola, L.).

16. *Gasterostomum armatum,* Molin. Cæca and duodenum of—
Sculpin (Acanthocottus scorpius, L.).
Sea-raven (Hemitripterus americanus, Storer).
Cusk (Brosmius brosme, Müller).
Halibut (Hippoglossus hippoglossus, L.).

17. *Distomum sp.* (Linton, 1901, Plate XXXII., f. 359.) Intestine of—
Halibut (Hippoglossus hippoglossus, L.).
Sea-raven (Hemitripterus americanus, Storer).

18. *Distomum sp.* (Linton, 1901, Plate XXXII., f. 354.) Stomach and intestine of Killifish (Fundulus heteroclitus, L.).

19. *Distomum,* sp., an undescribed species. Intestine and cæca of Halibut (Hippoglossus hippoglossus, L.).

20. *Distomum,* sp., an undescribed species. Urinary bladder of Wolf-fish (Anarrhicas lupus, L.).

21. *Distomum,* sp., an undescribed species. Intestine of Wolf-fish (Anarrhicas lupus, L.).

22. *Distomum,* sp. (appendiculate). Intestine of Angler (Lophius piscatorius, L.).

23. *Distomum,* sp. (immature).—In black, fibrous cysts in stomach-wall of Angler (Lophius piscatorius, L.).

24. *Distomum, sp.* (immature). Encysted in skin of Cunner (Ctenolabrus adspersus, Walb.).

To this list may be appended:—

Distomum, sp. (immature). Intestine of the Squid (Ommastrephes illecebrosa).
Distomum, sp. (immature)). In the parapodia of an Annelid, Nereis virens.

MONTREAL, February, 1903.

XI

THE EGGS AND EARLY LIFE-HISTORY OF THE HERRING, GASPEREAU, SHAD AND OTHER CLUPEOIDS.

BY PROFESSOR EDWARD E. PRINCE, DOMINION COMMISSIONER AND GENERAL INSPECTOR OF FISHERIES FOR THE DOMINION OF CANADA.

(WITH THREE PLATES.)

In view of the economic importance of the herring family (the Clupeidæ), of which some species, such as the sea-herring, the shad, sardine, &c., have a high commercial value, it is a matter of surprise that accurate information regarding the habits and life history of most clupeoids is not available, or, at any rate, not generally accessible. For a long period the most absurd opinions prevailed respecting the migrations and spawning of so familiar a member of the family Clupeidæ as the common herring of the Atlantic ocean and the North Sea. Pennant's version of the theory, universally accepted a century and a half ago, is so often referred to in works on fishing industries, that I quote somewhat fully from his 'British Zoology,' vol. III., London, 1769. 'The herring,' he says, 'are met with in vast shoals on the coast of America as low as Carolina, and in Chesapeake bay there is an annual inundation of those fish, which cover the shores in such quantities as to become a nuisance. We find them again in the seas of Kamtzchatka, and possibly they reach Japan,* for Koempfer mentions, in his account of the fish of that country, some that are congenerous. The great winter rendezvous of the herring is within the Arctic circle; there they continue for many months, in order to recruit themselves after the fatigue of spawning, the seas within that space swarming with insect food, in a degree far greater than in our warmer latitudes. This mighty army puts itself in motion in spring. we distinguish this body by that name, for the word "herring" is derived from the German "Heer," an army, to express their numbers. They begin to appear off the Shetland isles in April and May; these are only forerunners of the grand shoal which comes in June, and their appearance is marked by certain signs, by the numbers of birds, such as gannets, and others which follow to prey upon them; but when the main body approaches, its breadth and depth are such as to alter the appearance of the ocean. It is divided into two distinct columns 5 or 6 miles in length and 3 or 4 in breadth, and they drive the water before them with a kind of rippling, sometimes they sink for the space of 10 or 15 minutes, then rise again to the surface, and in bright weather reflect a variety of splendid colours, like a field of the most precious gems. . . . . . . The first check this army meets it divides into two parts, one wing takes to the east, the other to the western shores of Great Britain, and fill every bay and creek with their numbers; others pass on towards Yarmouth, the great and ancient mart of herrings; they then pass through the British channel, and after that in a manner disappear. Those which take to the west, after offering themselves to the Hebrides, where the great stationary fishery is, proceed towards the north of Ireland, where they meet with a second inter-

* There is an important herring fishery in Japan to which I refer on a subsequent page.

ruption, and are obliged to make a second division; the one takes to the western side, and is scarcely perceived, being soon lost in the immensity of the Atlantic; but the other, which passes into the Irish sea, rejoices and feeds the inhabitants of most of the coasts that border on it. These brigades, as we may call them, which are thus separated from the greater columns, are often capricious in their motions, and do not show an invariable attachment to their haunts. . . . . . Though we have no particular authority for it, yet as very few young herrings are found in our seas during winter, it seems almost certain that they must return to their parental haunts, beneath the ice, to repair the vast destruction of their race during the summer by men, fowl and fish. Some of the old herring continue on our coasts the whole year; the Scarborough fishermen never put down their nets but they catch a few; but the numbers that remain are not worth mention in comparison to the numbers that return.'

Dr. John Johnston, in his famous Historia Naturalis, De Piscibus et Cetis, lib. V., Amsterdam, 1657, ventured to give a more detailed account of the herring migrations off the British islands. His quaint Latin narrative may be thus rendered: 'Wonderful indeed are the particulars of the migrations of the herring. In former days they lingered in Norwegian waters as their home; but in our time they swim all round Britain in immense armies. About midsummer they seek the Scottish shores from the deeps, and they descend upon the English coast, being taken from Scarborough Castle to the Thames from the middle of August. Afterwards some are carried by currents into the English channel and there offer themselves to the fishermen until Christmas. Thence they swim along both sides of Ireland to the north ocean, as if circumnavigating Britain, and then disappear until June. Later they return as soon as winter is over.'

It is due to Mr. John Cleghorn, of Wick, Scotland, that this marvellous story of the herring's movements from northern waters was first discredited. In a paper read before the British Association, at Liverpool, in 1854, he set forth the following considerations unfavourable to the generally accepted theory:—

(1) Herring remain within narrow limits as local races, distinct in size, quality, time of spawning, &c., and do not migrate over immense distances. (2) Increased netting has not increased the total yield as compared with the previous twenty-five years, owing to the depletion of the local schools. (3) Catches at particular stations may be vastly increased; but the fish in restricted areas may be exterminated.* (4) On extensive open shores herring survive in numbers longer than in circumscribed areas, especially near large cities, where the fish always decline and disappear first.

There is now a general consensus of scientific opinion that all the important species of food fishes are local in their distribution and migration, the herring being no exception to this general rule. Not only are local varieties of herring distinguishable, but even on the same parts of a coast the herring schools have been separated into littoral and deep-water varieties. Thus, in Norway, a shore herring has been recognized, while a deep-water herring, which comes inshore at the spawning time only, has been similarly distinguished. Such littoral and deep-water schools of other marine creatures may exist, so that the fishermen of Nova Scotia who speak of the deep-water lobsters are no doubt right in regarding them as distinct from those habitually haunting the areas close inshore. The herring, on most shores where attention has been directed to the matter, appear to move off into open or deep water after spawning, the schools which continue to linger near shore being small and unimportant. It is, indeed, this existence of local schools of all kinds of fishes, which ensures most effectively the continuance of the fisheries as a commercial resource. Were the herring of a sea, like the North sea or German ocean, to move annually in one great body, it might be possible by effective and vastly increased methods of destruction to imperil them with

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*Amongst the statements of the Royal Commission on Scottish Herring Fisheries, 1879, this occurs: 'Either from the operations of man, or from some other cause, the herrings have been deterred from entering firths and sea-locks in the same numbers as formerly.'

total extermination, but the onslaught made by man and by the natural enemies of the finny tribes cannot destroy utterly all these local schools, to which reference has been made, and the recuperation of even depleted areas from more populous areas is no doubt Nature's method of constant restoration.

On the shores of Britain, excepting perhaps the southern shore, there are two spawning seasons annually for herring. Professor Huxley, in 1862, distinguished the spring and autumn spawning schools. Their periods of spawning are January to March, and from the end of August to the end of September,* the earlier spawning schools vastly surpassing in numbers the later or autumn schools. The migration inshore of the fish about to spawn reveals a remarkable serial succession as the fishermen move from their northern fishing grounds to the south with the progress of the season. The following table shows the dates, from May to December, at which the herring fleet operates on the coasts of the British isles:—

BRITISH HERRING FISHERIES STATIONS.

—	Miles Distance from Land.		Months.	
	From	To	From	To
Scotland—				
Stornaway	15	20	May 12..	June 21
Shetland	2	10	" 15..	July 15
Orkneys	3	16	July 15..	Sept. 6
Wick	25	60	"	" ..
Lybster	10	40	"	" .
Helmsdale	15	30	"	" ..
Banff	40	60	" 14..	" 30
Fraserburgh	5	65	" 1..	" 15
Peterhead	15	60	June	" ..
Aberdeen	30	70	" ...	" ..
Stonehaven	30	70	July 10..	" 3
Montrose	5	50	" 10..	" 13
Anstruther	15	60	"	" ..
Leith	15	20	June ..	" ..
Eyemouth	3	35	" 12..	July 30
England—				
Berwick	10	70	"	" ..
Sunderland North	5	70	" ...	" ..
Shields	10	70	July ...	August ..
Sunderland South	10	60	"	" ..
Hartlepool	10	50	" ...	" .
Whitby	4	30	"	" ..
Flamboro' Head	8	50	"	" ..
Dimlington and Spurn	12	35	August....	Oct. .
Cromer	10	30	Sept. ...	" ..
Yarmouth	7	40	October....	Dec. ..
Lowestoft	7	40	"	" ..
Southwould	6	40	"	" ..
Ramsgate	8	30	Nov.	" ..
Dover	6	15	"	" ..
Dungeness	5	15	"	" ..
Hastings to Beachy Head	5	15	"	" ..
Plymouth	4	10	Dec.	Jan. .
Ireland—				
Kinsale	6	20	April ...	June ..
Fastnet Rock	10	20	"	" ..
Gailey Head	6	20	"	" ..
Queenstown	12	60	"	" ..
Isle of Man	6	30	" ...	" ..

* This is clearly shown by the Scottish Fishery Board's Reports, as the 'Crown' brand for 'full' herrings is affixed during the two periods, viz., February and March and again in July and August.

In Canada there is a spring and fall migration of the herring, the earliest fish coming inshore as early as the month of March, or as soon as the ice disappears; but they are of small size, poor in condition, and used chiefly for bait in cod fishing. Later the fine fat bank herring move easterly from the west, and are taken some distance off shore, but in June and July the best herring for market purposes are generally taken. The spring spawners deposit their ova in shallow water in May, while the fall spawners come in in the months of September and October, and besides containing large roes or milts are of much larger size than the earlier runs. On the Labrador coast very large herrings are taken, the season commencing as a rule at the end of August, and being carried on in September and October. They are regarded as of very superior quality.

Owing to its vast commercial importance, it is not surprising that the herring has formed the subject of many reports and disquisitions. In 1864 the well-known work treating solely of the herring, by Mr. J. M. Mitchell, appeared. It was entitled 'The Herring, its Natural History and National Importance,' and in that work the Arctic migration theory was finally demolished. Accurate information upon the eggs of the herring and the spawning grounds was long wanting, but the eminent Professor G. J. Allman, on March 1, 1864, assisted by Dr. Bain, obtained off the Isle of May, on the coast of Fife, a quantity of herring spawn which was found attached to the rocky bottom at 14½ to 20 fathoms depth. In February and March, spawning, or 'full' herring were known to occur there in quantity, and dredges were used and divers were sent down in order to secure the eggs deposited under natural and normal conditions. The nature of the eggs and their mode of attachment to the sea bottom was thus finally settled. In 1874, some interesting experiments were carried out at Kiel, in Germany, the herrings' eggs being artificially fertilized and incubated under the supervision of a special commission in May, and the young fry, after hatching, were kept until the yolk bag was exhausted in the sixth day. Other eggs were obtained, later in the same year, and carefully studied, viz., in October. The United States Fish Commission, four years later, hatched herring at Gloucester, Mass., and in 1883, Professor Ewart, Mr. J. T. Cunningham, and Dr. J. Gibson, carried out further hatching experiments in Edinburgh. An exceedingly able naturalist, the late Mr. Geo. Sim, of Aberdeen, treated fully the spawning and feeding habits of the herring, in certain original papers, notably one included in the Edinburgh Fisheries Exhibition Essays, 1882, while authorities such as Meyer, Heincke, Dr. F. Day, Duncan Matthews, George Brook, Prof. J. A. Ryder, Mr. E. W. L. Holt, and Drs. McIntosh and Masterman, have added greatly to our knowledge of the herring and allied species. More recently Ehrenbaum, P. P. C. Hoeck and others have published fine memoirs upon the subject, and references to these will be found on subsequent pages.

A valuable series of young Clupeoids was recently obtained by me in certain rivers and harbours in Nova Scotia and New Brunswick, and formed the subject of my study at the Canadian Marine Biological Station, and I am able to add to our knowledge of these fishes, especially the anadromous alewife, kyack or gaspereau (*Pomolobus pseudoharengus*, Wilson, and *P. æstivalis*, Mitchell), and to present in succinct form my researches, along with the results of various other scientific workers, I also include some notes made on the gaspereau spawning grounds on the Washademoak lake, St. John river, New Brunswick.

My first acquaintance with Clupeoid ova dates from April, 1885, when a batch of herring eggs, handed to me by Professor McIntosh, of the University of St. Andrews, occupied my attention, and I made drawings of the ova and of the young fry when they hatched out. These eggs, picked off the cart of a fish 'cadger' or pedlar in St. Andrews, Scotland, were placed in the tanks of the Marine (now the Gatty) Laboratory, where they were duly incubated. The eggs had been squeezed out of the ripe herring by the pressure of the fish heaped up in the cart, and in the mixed mass the sperms from the ripe males mingled with and fertilized the ova. The sun's rays had dried the outside of the spongy masses, and the inner eggs survived as clear glassy globes about 1/20 of an inch in diameter, thus convincingly

demonstrating the hardy nature of the herring's eggs, a feature to which Professor McIntosh drew attention as a fact of vast importance from a fishery point of view. Indeed sufficient attention has not been directed to this fact, emphasized by Professor McIntosh, for there can be no doubt that the continued plenitude of the herring in waters, where immense fisheries have been carried on for centuries, is largely due to this hardiness to which that eminent authority drew attention.

Man is but one of a multitude of destructive agencies making war upon the herring; whales, porpoises, seals, &c., storms, high tides and other physical causes, all add to the destruction. In Gloucester, Kent, and Northumberland counties, New Brunswick, herring spawn is heaped up knee-deep for many miles, after severe gales, in some seasons, and is then carried on to the fields for manure. 'It is impossible,' wrote Dr. Pierre Fortin, a Canadian inspector, more than forty years ago, 'to form a correct idea without seeing it, of the immense abundance of ova of the herring deposited on the Canadian coast, where the herring spawns. I have seen the shore at Pleasant bay, Magdalen islands, covered 2 or 3 feet deep with them for several miles, and oftentimes on returning to my vessel I have seen the sea white with milt for several acres round, though when I passed the same spot two hours before the water was of the usual colour.' On the Pacific coast of Canada the herring schools are no less abundant, indeed they are even more plenteous. From the Straits of Georgia to Queen Charlotte islands, and still further north along the Alaska shores belonging to the United States, the herring are incredibly abundant. Near Nanaimo, Vancouver island, the harbours and bays appear to be filled with solid masses of moving herring, and I myself in February, 1902, passed through a floating mass of dead herring extending for over two miles as I travelled on the mail steamer from Vancouver to Nanaimo. Whether these fish, which floated in a mass two or three feet deep, die from suffocation, being crowded in narrow inlets and bays, or from submarine explosions or poisonous volcanic influences, has not been determined. In 1883, Burrard Inlet, near Vancouver City, was filled with herring, and by seining on a very small scale over 1,700 barrels of herring were secured, with little labour, which were salted and shipped to Australia, where there was an eager demand for them. Herring oil extracted by cooking and pressure was valued years ago at 40 cents per gallon, and the refuse remaining was converted into fertilizer material. The Alaska Oil and Guano Company, the principal United States producers of herring products on the Pacific coast, sent in 1900 into the markets no less than 172,000 gallons of herring oil, extracted from about 60,000 barrels of herring, besides 1,200 tons of guano (valued at $26,400), and 192 barrels of salted herring, valued at $960, the oil alone bringing $34,000. Other United States companies put up in the same season 3,000 barrels of salt herring, valued at $14,000. The British parts of the Pacific coast are regarded as even more productive, and a great herring industry lies open for development. Certain bays along the Tsimpsean peninsula and at the northern end of the Queen Charlotte group, are crowded with fine herring in the spring.

On the western Pacific shores the herring are plentiful, and there is a very important fishery on the coast of Japan, where they come in in immense schools from the outside sea to spawn at the end of spring and in the early summer. The west shores of Hokkaido are famous herring resorts; but the schools are generally distributed where there is a cold under-current in spring.

It may be added that over 40,000 barrels of herring are used annually on the Atlantic coast in the lobster fishery of Canada, the value at $1 a barrel thus amounting to $40,000.

Other Clupeoids, such as sprats, pilchards, shad, gaspereau, &c., appear in similar stupendous quantities when moving to their spawning grounds, or schooling for other purposes. 'I have seen,' said Dr. Matthias Dunn, the Cornwall fishery authority, 'a single porpoise drive tens of thousands of pilchards at will, as easily as a dog could drive a flock of sheep.'

The Basque sardine fishermen take advantage of this habit of the porpoise (marsouin), and surround sardines and porpoises with their seine, permitting the porpoises

later to escape, as M. J. Kunstler describes (*La Question Sardinière,* Bordeaux, 1904): 'Pour pêcher, on recherche une bande de marsouins quel 'on suit jusqu'à ce qu'elle ait réussi à former un banc compact de sardines. Puis la senne est mise à l'eau, en même temps que les rameurs impriment au bateau un assez rapide mouvement en cercle. On entoure ainsi les marsouins aussi bien que les sardines.'

The eggs of the herring family have as a rule the form of small translucent glassy spheres, possessing a strong hard shell like thin transparent horn. They may cling together in spongy masses as bunches, or form a film of transparent pellets, on stones, algae, shells, &c., and leaving interspaces through which the water can flow freely, and thus aerate the eggs, or they may have the buoyancy of pelagic eggs and float freely at the surface (like the pilchard's and sprat's eggs), or lie loosely on the bottom, as is the case with the ova of the shad. Eggs which cling together like those of the herring are coated with a tenacious mucus, and as they fall through the water they are fertilized by the milt of the male. which beclouds the water. and on reaching the bottom the external cement hardens so that they bunch together, or cling firmly to foreign objects. Mr. Joel Ingersoll stated to the New Brunswick Herring Fishery Commission, in 1836, 'At Seal cove and Whale cove, at Seal cove particularly, (on Grand Manan island) I have seen the net warp become as thick as my arm with the herring spawn, and the nets and anchors covered also,' while Mr. Samuel Chaney, of Grand Manan, said, 'I have seen it on anchors and warps and on the nets in great quantities.'

In British Columbia the Indians lay twigs and tree branches on the shallow herring spawning grounds, and after they are coated with the eggs, they take the twigs out and either eat them, raw or dried, by nibbling the branches between their teeth, devouring the eggs as a great dainty.

All the Clupeidæ have not dense heavy eggs, as already pointed out. There are, indeed, three types of ova:—

(1) The demersal or non-buoyant eggs which cling together and are attached to adjacent objects at the bottom, of which the sea-herring is an example. The alewife, kyack, or gaspereau, produces non-floating eggs, not so dense as the herring's but much heavier than those of the shad and less than one-half the diameter of the shad's eggs. They adhere to each other and to stakes, stones, &c., under water, and measure about $\frac{1}{20}$ of an inch in diameter (1·27 mm.). They are fairly hardy, and survive conditions that would be fatal to the eggs of the shad.

(2) The semi-buoyant eggs like the delicate spherical ova of the shad, $\frac{1}{8}$ or $\frac{1}{7}$ of an inch in diameter (3.29 mm.), and very pale amber in colour (Plate IX., fig. 22). The ball of yolk (*a*), which only fills about one-sixth of the chamber of the egg capsule, is very granular but contains no large oil-globule. The eggs are tenacious when laid, but harden under water, and do not cling to adjacent objects. They simply roll loosely on the rock, sand, or shelving flats in the non-tidal parts of rivers, where the shad spawns. The Twaite Shad (*Clupea finta* Cuv.) occurs in Britain and in European waters, but has not been recognized on this continent, though it is possible that it inhabits our coasts; indeed as Mr. Thomas F. Knight, in 'The River Fisheries of Nova Scotia' (Halifax, N.S., 1867), says, 'It is said by the fishermen of the Bay of Fundy that there are two species or varieties . . . . . This opinion is not confirmed by any description of the shad by naturalists; they know of but one species.' It produces an egg (Plate IX., fig. 21) quite different in size and other features from the common shad or Allis shad, as it is called in England. It is a much larger ovum than that of *Clupea alosa,* being $\frac{17}{100}$ of an inch in diameter (4·25 mm.). Dr. Ernst Ehrenbaum has studied very carefully the egg of this species at the Biological Station, Heligoland, and he refers to a peculiar reticulated character possessed by the shell or egg capsule: thread-like thickenings forming a rectangular network, like a fine basket-work pattern, so that the shell externally appears as if divided into minute squares, some being incomplete (Plate IX., fig. 25). Ehrenbaum describes the egg in detail (Beiträge zur Naturgesch. einig. Elbfische, Wissensch. Meersuntersuch, Bd. 1), as well as the larval, post-larval and adult life-history, and on a later page I refer to his elaborate account.

(3) Finally, there is the typical pelagic or floating egg of some Clupeoids. All pelagic eggs are marked by translucency, buoyancy and extreme delicacy of structure; but the eggs of the sprat (*Clupea sprattus*, L.) and the pilchard or sardine (*Clupea pilchardus*, Walb.) are of unusual delicacy and buoyancy. The ova named are practically spherical; but one clupeoid ovum of the pelagic type is quite ellipsoidal, viz., that of the anchovy (*Engraulis encrasicholus*, L.). The eggs of the sprat were first discovered by Hensen in the Baltic, and were studied in detail by Professor Pouchet in Britanny, and Mr. J. T. Cunningham, who obtained them in the Firth of Forth. They are about 1/25 of an inch (1·016 mm.) in diameter; some, not perfectly spherical, measuring 1/20 × 1/25 of an inch (1·01 × ·99 mm.), and the capsule is extremely tenuous, while the clear colourless yolk, which almost completely fills up the capsule, shows delicate interlacing lines or reticulations as though the yolk were incompletely divided into spheres. The pilchard's egg is similar, about ⅛ inch (3·8 mm.) in diameter, of extreme translucency, but the yolk occupies only a portion of the chamber of the capsule. The yolk substance is divided into spheres, and in its midst is seated a large oil-globule.

The spawning season, breeding habits, number of eggs produced, and the time occupied in incubation, show great variation in the Clupeidæ. We have seen that the sea-herring spawns at two different seasons in the year, and that special areas are selected year after year, where the sea-bottom presents suitable features for the deposition of the eggs, a hard bottom being a necessity, and usually of a rough shingly or rocky nature. They spawn in 10 to 20 fathoms of water, the eggs, deposited by the ripe female, being fertilized before reaching the bottom, where they adhere to zoophytes, stones, &c. The number produced by one herring is found to range from 10,000 to 30,000 or 40,000, or even 60,000, and at 53° F. they hatch out in six to eight days, while at 33° or 34° F. they take thirty to forty days. Some recent observations by Dr. Jenkins embody many interesting results both as to the comparative productiveness of different varieties of the sea-herring, and the proportions of male and female found in certain captures of the fish carefully examined. He ascertained that eight autumn herrings had in different cases from 13,000 to 65,000 eggs, while five spring herrings had from 25,264 to 45,543, the mean number for the lot being 30,000. Dr. Fulton found that sixteen spring herrings had a mean of 31,768 eggs, the numbers in different fishes varying between 21,500 to 47,466. Jenkins shows that the number varies with the size and age of the fish, the smaller and younger having fewer. With regard to the proportion of the sexes authors are not quite agreed. Fulton found that among 3,457 examined 1,724 were males and 1,733 females, while Heincke found 822 females and 606 males among 1,488, and Jenkins 148 females and 155 males among 303.

On a lake near Kiel where the water is brackish, and communication with the sea has been cut off, ripe herrings were found to be considerably smaller than those got in the Baltic, and to have a lower fecundity. Five, for example, contained only from 4,245 to 7,950 eggs, the average being 5,615, and the earbones showed that the herrings were three years old, while their average length was 5⅜ inches, and their average weight 16·1 grammes, or a little over ½ ounce. The average length of the autumn Baltic herring of similar age was 7 inches, its weight 39·5 grammes (1⅜ ounces), and the number of its eggs 15,709.

The sprat and pilchard, having pelagic or floating eggs, scatter them freely in the sea, and although certain spawning areas seem to be selected by these fish each year, the eggs they produce must be widely scattered in the water. The former spawns very early in the year, viz., January to May,* while the pilchard is later, probably May and June, or even subsequently, while in more southerly waters the period is in winter and early spring. Mr. J. T. Cunningham hatched out pilchard eggs in three days and the sprat take about the same short time, indeed the Clupeoids appear generally to develop rapidly, and whereas the salmon, trout and similar fishes, with large, heavy eggs, take from 90 to 160 days, normally rather less than the latter period, and even cod, had-

* Professor McIntosh obtained specimens abundantly early in May at St. Andrews, Scotland.

dock, flounder, and species which deposit small floating eggs in the sea, take from 15 to 30 or 40 days unless the temperature be high, when 9 to 10 days may be the time occupied in incubation, all the Clupeoid eggs hitherto studied appear to pass through the stages of embryonic development far more rapidly than the fishes above referred to. With the shad, and gaspereau or alewife, the conditions of spawning are wholly different, for both these fish leave the sea, which is their habitat, to spend a few weeks in rivers up which they ascend to spawn in fresh water at no great distance above tide limits. When the water temperature is 56° to 60° F., in late May or in June, the shad pass into their customary rivers, the males preceding the females. They ascend with considerable rapidity, and within 12 to 14 days are found crowded on the shallow sandy or pebbly areas, generally some tributaries of a large river, and deposit their minute semi-buoyant spawn. The number each fish produces is about 30,000, though large examples have been known to yield 60,000 eggs, or even double that quantity. They hatch out in 7 to 10 days, when the clear shallows are found to be alive with the wriggling jelly-like little larvæ. The alewife or gaspereau is usually somewhat earlier, and enters the rivers about the last of April or the early part of May, when the waters are in flood. They often mingle with the shad which follow them, so that the nets set for shad capture gaspereaux in great quantities. They are able to surmount falls and dams, if not more than 2 to 2½ feet high, throwing themselves spasmodically forward and flapping the tail vigorously. The strongly serrated abdomen is said to aid in surmounting difficulties, but this is probably not so. Having gained the calm upper waters some distance above the reach of the tide, the spawning immediately commences. On moonlight nights the shallow waters present a much-disturbed appearance owing to the energetic movements of the mating fish, whose tails and fins project above the water as they rush hither and thither. In a few nights the process is over, and the fish within three weeks of their ascent are found descending in a very thin emaciated condition. Some remain until July, but as the eggs take a very short time in hatching out, the young fry are found abundantly before the end of June, as transparent worm-like creatures less than one-fifth of an inch long (4·84 mm.). The ova are smaller than those of the shad, viz., about 1/20 of an inch (1·86 mm.), and they cling together by means of their adhesive capsules in masses, becoming attached to stakes, submerged roots, stones, &c. The yolk fills up the capsule, as in the sea herring and sprat, not leaving a large perivitelline space, as is the case with the eggs of the pilchard and shad.

It is an interesting circumstance that young larvæ of the Clupeidæ are not only distinguished by their exceptionally delicate structure and appearance, but by the absense or very sparse presence of colour spots or pigment. There is usually a linear series of black stars or minute spots along the straight elongated digestive canal and intestine (Plate VIII., figs. 2, 3, and Plate IX., figs. 14 to 16); but not scattered, as in so many young larval fishes, over the body, cranium, and embryonic fin-membranes, or even over the yolk-sac hanging below the body of the fish. But the most distinctive feature is the position of the anal opening or termination of the intestine—this aperture being in most fishes at a point distant about one-third of the body's length from the snout, more or less, some species having the anus midway along the ventral margin of the body; but in the case of herring, sprat, shad, pilchard and clupeoids generally, it is at a point about four-fifths distance along the under side of the body, and very near, therefore, the basal portion of the tail. The position is slightly nearer or further from the tail in different species, but in all it is so far posterior in position that a clupeoid larva can be immediately determined by that feature. Even in a non-clupeoid like the sand-eel (*Ammodytes*), with the anal opening apparently far back (*vide* McIntosh and Prince, Life Histories of Food Fishes, Roy. Soc., Edin., Vol. XXXV., 1890, Pl. XIII., figs. 6 and 7), it is nevertheless about semi-distant along the ventral line; and in the smelt its position is fully three-quarters of the body-length from the snout. Further, the notochord is in a number of cases quite diagnostic in appearance. This cartilaginous rod or primitive backbone is divided up into a series of seg-

ments, like a horizontal column of draughts or disks in the herring, sprat and pilchard (Plate VIII., figs. 1, 2, 6, 7, 8 and 9), but in the shad and gaspereau (Plate VIII., figs. 10 and 11), its structure is that of an irregular network, or complex meshwork, as in most cases not belonging to the herring family. This peculiar regular arrangement of the notochordal cells is a striking feature and facilitates the recognition of many newly-hatched Clupeoids, when mingled with other fish-larvæ; but the extremely posterior position of the anus, usually with a little bay or indentation in the ventral marginal fin (Plate VIII., fig. 11, and Plate IX., figs. 17, 18, 19), and the regular series of stellate black spots, either in a single or double line, along the upper or the lower contour of the digestive canal, are, as far as at present known, characteristic of all the herring family. Other stellate spots of a black colour, few in number, may occur on the head around the cylindrical kidney tubes or on the caudal fin-expansion at the posterior termination of the notochord. These fishes, therefore, present a great contrast to the young stages of the majority of species of other families, in which elaborate arrangements of colour, yellow, reddish brown, orange, ochre, black, purple, blueish and greenish spots may occur, massed in many species as bars or patches along the body. The surface of the protruding yolk-sac may also be brilliantly diversified as well as the wide marginal fin-membrane. As the yolk and fin-membranes and the body generally in the herring, shad and clupeoids are usually colourless, their delicacy of structure and glassy transparency are thereby increased. Some, as the sprat, show absolutely no pigment at all when they emerge from the ovum (Plate VIII., fig. 8). The yolk, moreover, in most species, is comparatively small compared with the length of the elongated eel-like body, and does not form the exaggerated protruberance seen in so many fishes, *e.g.*, salmon, trout, cod, &c. On comparing the newly-hatched larvæ of various species of clupeoids a considerable variation in their length is observable, the length of the sprat (*Clupea sprattus*) from the tip of the snout to tip of the tail is 3 :6 mm. (1/7 inch), the pilchard (*C. pilchardus*), 3.8 mm. (⅛ inch); the alewife or gaspereau *(Pomolobus pseudoharengus,* Wilson), 5 mm. (⅕ inch); the sea-herring (*C. harengus,* L.), 5 to 7 *mm.* (7/24 inch); the Twaite shad (*Clupea* or *Alosa finta, Cuv.*), 4·25 mm. mm. (less than ⅙ inch, *i.e.*, 4/24), and the common shad (*Alosa sapidissima,* Wilson), 9·29 mm. (9/24 inch). Thus, the pilchard would appear to be rather more than one-third of the length of the shad, the gaspereau rather more than half, the Twaite shad less than half, and the sea-herring considerably more than half the size, while the sprat is about the same length as the pilchard on hatching. This variation is a most striking one, but it is no key to subsequent growth during the larval and post-larval stages of the species referred to.

By the sixth day after hatching, the Twaite shad (Plate IX., fig. 13), according to Ehrenbaum, doubles its length, being 8·7 mm., or rather more than ⅓ inch: a length which the sea-herring does not attain until about the tenth day, though the herring, as above noted, is a much larger larva when it issues from the egg. The shad, like the sea-herring, almost doubles its length in ten days, measuring 15·73 mm. (15/24 inch), while the pilchard is stated to be 24 mm. (24/25 inch) at that age, a measurement which no doubt needs confirmation by further observation. By the twentieth day the herring (Plate VIII., fig. 2) exceeds 10 mm. in length (⅖ inch), the Twaite shad (Plate IX., 14) is 28/50 of an inch, and the common shad (Plate IX., fig. 19) 36/50 inch, or about 19 mm. When double the age just mentioned, *i.e.*, on the fortieth day, the herring is a little over half an inch long (2·69 mm.), the gaspereau is about the same length, 14 to 15 mm. (Plate VIII., fig. 10), but the shad still exhibits remarkable growth, being on the thirty-fifth day 56 :95 mm. long, *i.e.*, 2 to 2¼ inches long (Plate IX., fig. 20), while the Twaite shad, on Ehrenbaum's authority, is barely ⅘ inch (20 mm.) (Plate IX., fig. 15), and reaching on the forty-third day a length of nearly an inch, 24 mm. (Plate IX., fig. 16). At the age of two months, or, to be more accurate, on the seventieth day, the herring exceed 72/100 inch (18·9 mm.), whereas the shad is now 3 or 4 inches long (75 to 100 mm.), while by the fourth month the shad is stated to have doubled its length, being 5 to 7 inches long (125 to 175 mm.), as compared with the

sea-herring of the same age, which is 29 mm., or about 1¼ inches long. The gaspereau, from an experiment reported to have been carried out in Maine, U.S., by Messrs. Treat & Son, reaches a length only half that of the shad at the age when the shad is 3 to 5 in. long (4 months old). Of course, such fishes, when confined in rearing ponds, are probably dwarfed in their growth, and may not afford a certain clue to the determination of the age of specimens captured in their native waters. Shad have, for instance, been taken 3 to 4 inches in length in February, while specimens of the same length have been secured in great numbers in September; and in the Potomac river examples 3 inches long are abundant in November, while about the first of that month shad 5 to 7 inches long are plentiful in the Maine rivers. According to my observations, the first-named specimens (3 to 4 inches long) must have been hatched out in November or December, a supposition which raises a difficulty, as shad enter rivers, in December and January, on the Atlantic coast, only as far south as Georgia and Florida, while the small shad of the size named, captured in September, as in the Potomac river, must have been hatched in June, though the main ascent is as early as April in that river. Shad 9 to 13½ inches long are frequently taken in Canadian waters in October, and as these fish cannot possibly be only four months old, and must be the young of the year preceding, especially as shad 3 or 4 inches long are also captured about the end of October, and schools of fish 4 to 5 inches long are observed in December. We know that shad are apt to migrate along long distances of sea shore, as on the Pacific coast, where they have spread far from the rivers where they were originally planted, so that they are not so true to their native rivers as the salmon, and this may explain the very discrepant nature of the facts alluded to. In Florida shad ascend rivers in December, as already stated, while in the Savannah and Edisto rivers of Georgia they are found in January, in the Potomac in April, Delaware river in May, and in the Canadian rivers from the middle of May (in St. John river, N.B.) to the end of June, especially in the more northerly rivers, as the Miramichi. A month later, in July or August, the spawned fish descend to the sea again in very poor emaciated condition, and the young fry begin to descend about the same time, but go down more slowly.

It is, of course, a matter of much difficulty to trace the later history of the various species now under review, but some principal facts may be determined. Thus the small sea-herring 62 mm. (2½ inches) long taken in September cannot possibly be the fry of the July spawning schools, as such fry could not be more than about 1 inch long according to the foregoing account, nor is it possible for the fry hatched in April, May or June to be more than 1½ to 1⅝ inches long, making all allowance for great variations in growth. The herring 1⅞ to 2 inches long found in January off the east coast of Scotland must be five months old, if they are, as Mr. Geo. Sim held, the fry of the August preceding, while similar young fish in June and July must be March fry. In its second year a sea-herring is 60 to 80 mm. long (2½ to 2¾ inches), though Hjort states his views that a length of 2½ inches (50 to 60 mm.) may be reached in six months. The specimens of herring 3½ to 4½ inches frequenting St. John harbour in August (Plate I., fig. 5) are not likely to be the fry of the preceding spring and only four or five months old, nor of the previous fall (August or September), but of the spring or fall prior to that. A year later, when barely 3 years old, the fish are 4½ to 6 inches long (114 to 150 mm.), though Hjort again holds that in 2½ years a herring reaches 160 to 165 mm. (6¼ to 7 inches) in length.* Herring 8 to 11 inches long cannot be less than 3 years old, and may be in their fourth year. Dr. Meyer decided after his studies upon the herring (30 years ago) that herring 6½ to 7 inches long are only 2 years old, and that within one year after hatching they are 5 to 5½ inches long, an opinion not confirmed by more recent researches. Sars, Nilsson, Sundevall and others do not support Meyer's views. Dr. Jenkins in his recent studies at Kiel states that the Baltic herring show the following growth: 1st year, 4½ to 4¾ inches; 2nd year, 6⅓ to 6½ inches; 3rd year, 7½ to 7¾ inches; 4th year, 8½ to 8⅝ inches; 5th year, 9¼ to 9⅔

* The common opinion that the 'matie full' herring, 9 to 9½ inches long, in Scotland is only 2 years old can hardly be correct.

inches. The sprat, which on hatching out is only about half the size of the herring and one-third the size of the shad, is believed to reach a length of 3 inches in one year, in its second year it is said to be 4¾ inches and in its third year 5½ inches long, while the pilchard, which resembles the sprat in so many points in its embryonic and larval life-history, is believed to grow much faster during its post-larval life. Professor A. F. Marion declared that the rate of growth is half an inch (1cm.) per month, so that the translucent larva ⅙ inch long on hatching becomes a post-larval fish 1 to 1¾ inches long (20 to 40 mm.) when between one and two months old—a view very difficult to favour. The famous French authority holds that when 140 to 150 mm. they are ready to spawn and are not more than one year old. As compared with other Clupeoids a growth of a centimetre a month is of course unusually rapid. Mr. J. T. Cunningham obtained specimens which were only 8·5 mm. long (⅓ inch), and according to Marion's calculations these were less than one month old, while his other specimens (Mar. Biol. Assoc. Journal, Vol. II., p. 161, Pl. X., fig. 3) would be five months old, and the same size as the sea-herring at that age. Pilchards 3 to 4 inches long are abundant in October Mr. M. Dunn has recorded, and, at Marion's rate of growth, would be the fry of March or April ova; but on the Cornish coast, June, or even earlier, appears to be the spawning period, and it is impossible until more extended work has been done to accurately decide the rate of growth. It may be added that the southern or Mediterranean sardine is a smaller form (6 to 7¼ inches) than the northern sardine which ranges from 9 to 10 inches when adult, a size which corresponds with the Canadian pilchard (*Clupanodon cœruleus* Girard), of which mature specimens studied by me ranged from 209 to 237 mm. (8½ to 9½ inches).

The rate of growth is of first importance, as it is a guide to the age at which the various species of the herring family reproduce. The matter is one upon which authorities differ greatly. The common sea-herring was supposed by Professor Huxley to reach maturity in its first year, as De Caux had ventured to surmise before.* Mitchell held that maturity was reached in eighteen months, while Meyer favoured the second year, when the fish he thought were 8 inches long. but at the present time the prevailing opinion is that in the third or fourth year these fish reach the spawning condition as Sundevall, Ljungmann, Jenkins and others hold. Such a form as the dwarfed Caspian herring is of course exceptional, and is found to be ripe when only 4½ or 4¾ inches long, while land-locked herring such as the variety in the Windebyer Noor, near Kiel, spawns when 5⅜ inches long, and in its third year after being hatched. The Baltic herring spawn when 7 inches long. The sprat, a species only one-third the size of the shad, and half the size of the average herring and gaspereau, spawns when 5½ inches long (*i.e.*, in its third year), that species being 3 inches long in its first year and 4¾ in its second year.

The movements of the young clupeoids, larval and post-larval, are interesting, and while much variety of opinion has existed amongst authorities, there is now a consensus of view which may be summarized as follows: The young fry, when newly hatched and far more delicate and translucent than most other fishes in the sea or in rivers, lie on the bottom for some time. The shad, it is true, was stated by Mr. Seth Green, to seek the main current in midwater in the rivers where it is hatched. 'How different this (he said) from the young trouts that lie almost helpless for 45 days and then are fain to hide behind roots and stone! Whereas these minute, transparent, gelatinous things, push boldly for the deep swift current, where they are too insignificant to be attacked by the great fishes.' It may be pointed out that, when liberated from the Seth Green hatching boxes, anchored in a current, the fry were bound to take to the swift water, 'with their heads up stream,' such delicate organisms being carried by the current away from the shallows. My own examination of the spawning grounds and 'nurseries' on the St. John river convinced me that the pebbly shores

* Professor Huxley, in his famous address at Norwich Fishery Exhibition, April, 1881, on 'The Herring,' admitted he had overestimated the rate of growth, in view of the results of the Baltic Commission investigations.

are the normal resorts of the fry of shad and gaspereaux, the transparent young being invisible as they securely lie amongst the shingle, sheltered from the rushing stream of water overhead. Even the sea-herring, hatched out on spawning beds at some depth, do not mount at once to the surface, but lie at the bottom (this stage is figured on Plate VIII., fig. 1), until they reach a length of 10 mm. ($\frac{4}{10}$ inch). When slightly larger the yolk is absorbed and larvæ 10 to 24 mm. long ($\frac{4}{10}$ to $\frac{9}{10}$ inch), (Plate VIII., fig. 2), ascend to the midwater level, where they linger until an inch or more in length (24 to 28 mm.), when they are found floating in countless myriads in the surface waters. The transparent, worm-like, almost colourless clupeoid larva begins to acquire some pigment or spots of colour after the small sac of food-yolk, suspended under the body, is absorbed (Plate VIII., fig. 2). Indeed, in the herring the eye is bright and silvery on hatching out, and Mr. Holt states that the mouth is open (Ann. of Nat. Hist., 1889, p. 370), though this does not, from my own study of herring larvæ, appear to be always the case. When about 1 inch long the post-larval herring move inshore, lingering near river months until they are 2 inches long (Plate VIII., figs. 3, 4), when they resort to mid-water, and in the autumn following are again found inshore, having attained a length of 80 to 100 mm., *i.e.*, 3 to 4 inches (Plate VIII., fig. 5). I have obtained them in harbours in August and September congregating with the gaspereaux and shad in large schools. The shad appears to be the most precocious of the clupeoids in its early development. The yolk is absorbed by the fourth or fifth day after hatching (Plate IX., fig. 18), though a remnant remains, near the liver, until the fifteenth day, but minute conical teeth are developed before the end of the first week of larval life. The young fish develop rapidly, and within three months, though still delicate transparent creatures 2 to $2\frac{1}{2}$ inches long, they have all the fins well-developed, and the deep form of the adult is being assumed (Plate IX., fig. 20). Norris, in his 'American Fish-Culture,' Philadelphia, 1868, gives a figure of the shad at this stage (*see* Plate X., fig. 36), referring to it as three months old in the text, page 161; but a descriptive note, at the end, states that the fish represented, is two or three weeks old, a patent impossibility, and that it is copied from the first report of the Massachusetts Fish Commission. By November the young shad are 4 or 5 inches long and frequent estuaries and harbour mouths.* This stage is represented in Norris' book, figs. 2 and 3, opposite page 141, and as the figures are extremely interesting, I have copied them on my Plate X., figs. 37 and 38. The parent fish, it may be added, descend after spawning and are captured late in July or in August, in poor condition, hardly fit for food. Those that escape the estuary nets resort to sandy flats, to recuperate, which they do rapidly. At the head of the Bay of Fundy are extensive feeding grounds of the shad, where they improve and fatten so rapidly that the 'fall' shad are regarded as the choicest of all inshore fishes for table purposes.

The gaspereau, like the shad, undergoes rapid growth after hatching out in June, when it is 5 mm., or $\frac{1}{5}$ inch in length, for it trebles its length in about a month. I secured specimens in the Washademoak lake, River St. John, N.B., $\frac{5}{8}$ inch (15 mm.) long (Plate VIII., fig. 10), which were of extreme interest. As no published account of these larva has been given by me though I described them to Section IV., of the Royal Society of Canada, several years ago, I will briefly detail their main features. The extreme posterior position of the anus is marked, the otocysts are unusually large, a feature common in the herring family in the larval stages, the head is depressed and the colour spots are black, excepting a few yellow dots which appear around the pupil of the eye, and an orange patch occurs in the pronephric region, behind the pectoral fins. The large size of the translucent pre-anal fin is a notable feature. There are three rows of black spots at this stage, viz., a dorsal row from the crown of the head to the upper lobe of the tail, a second chain along the middle lateral line, and a third series along the middle abdominal line. I kept specimens alive and ten days later, when

* The capture on several occasions of shad 4 inches to $4\frac{3}{8}$ inches long in New York harbour indicates a much slower growth than that generally favoured.

the fish must have been 30 to 40 days old, they measured 16:5 mm. (13/20 inch) (Plate VIII., fig. 11), and the rudiments of the dorsal fin are now seen as delicate rays, while the front part of the lower jaw is studded with minute teeth. A maxillary flap hangs from the upper jaw, this maxillary flap being prominent also in the young shad (Plate IX., fig. 19). Further, the notochord, as in the shad, consists of a network of irregular cells, unlike the regular notochordal disks, characteristic of the herring, sprat, &c. At this stage the pre-anal lobe, of great length, still forms a prominent feature, and is probably diagnostic of the gaspereau, though it is prominent in such a form as *Ammodytes,* the sand-eel. The globe of the eye is now black with pigment and the swim-bladder is visible as a large silvery almond-shaped sac with pigment (black) in its dorsal wall. Pigment is more abundant over the whole of the fish at this stage, the head, cheeks and throat being spotted plentifully with black, amidst which a few yellow stands of colour pass. In this stage, as in the previous stage, the dorsal fin membrane is very narrow, and forms a thin, rather meagre membranous ridge along the back from the shoulder to the tail. The pre-anal fin is still of disproportionate length and breadth, indeed, its breadth almost equals that of the trunk, a very unusual feature in fish larvæ, although in the shad it is a fairly prominent structure (Plate IX., figs. 18, 19). The tail is more distinctly spatulate, the hind margin being no longer rounded, but markedly flattened. Between this stage 16·5 mm. (13/20 inch), and the stages figured on Plate X., fig. 26, when a size of 30 mm. (1⅕ inches) is attained, no intervening stages have been secured. The blunt rounded head, the stout, somewhat shortened body, and the large size of the eye and the paired fins, are in contrast to the similar stages of the herring (Plate VIII., fig. 4), and the shad (Plate IX., fig. 20). When 35 mm. long (1⅖ inches) (Plate X., fig. 27), the external features are practically the same, the pigment forming two lunate patches at the base of the tail being more marked; but the general translucency of the body is preserved and the pigment consists of very minute black specks scattered all over the dorsum, especially on the head and on the tail, a few spots occurring on the premaxilla, maxilla and mandible. Two features are worthy of special attention at this stage, viz., the shortness of the maxilla, which does not extend as far as a line drawn perpendicularly through the centre of the eye, whereas in the shad the maxilla extends considerably behind such a line (*vide* Plate IX., fig. 24), and in the herring (Plate VIII., fig. 5) barely reaches such an imaginery line, while again the snout is very acuminate and not bluntly rounded as in the shad and Twaite shad (Plate IX., figs. 23, 24). The strong serrations of the middle abdominal scales or scutes, so characteristic of the adult gaspereau, are already well marked (Plate X., fig. 29). A much older stage was obtained in St. John harbour, New Brunswick, about the middle of August, when specimens from 3 inches (75 mm.) up to 5 and 6½ inches (140 mm.) were secured (Plate X., figs. 28 and 29). The specimens could not possibly be the young of the same season, and though one in ten was of the small size first mentioned and a fifth of them of the largest size, all presented much the same features and were practically adult in general external appearance. The scales are comparatively large, and completely clothe the body, and they differ much in form and size from the scale of the sea-herring of the same size (Plate X., compare fig. 30, a gaspereau scale, with fig. 31, a sea-herring scale, both scales being from the dorsum near the base of the dorsal fin). Hardly less distinctive is the series of abdominal scutes or middle ventral line of keeled scales. These, in the gaspereau (Plate X., fig. 30) are much more strongly pointed and projecting than in the young herring (Plate X., fig. 31), while the strong anterior process (*a*) is absent, or represented by a mere indication of a process in the posterior bifid margin of the scale. The sides and opercular surfaces are brilliant silvery in appearance, while the dorsum is of a dark purplish blue, thickly spotted with black. The orange or ochre tint, noticed in the early larval fish, still remains as a suffused tinge though far paler than when the gaspereaux are 30 mm. long. The paired and unpaired fine are very deeply spotted with black, whereas in the herring the fins are clear and transparent, and bear no black

spots excepting the tail-fin and a portion of the dorsal fin. In many specimens the dark lunar patches at the base of the tail still appear, while the dusky patch on the shoulder, absent in the herring, is distinct and remains in the adult. The very distinctive features referred to, and there are many others, are of aid in at once separating young gaspereaux from young herring of the same size with which they congregate in estuaries and harbours, or from the young shad, which are natives of the same rivers, though they do not seem to be as a rule found associated in the same schools of clupeoid fry.

The subsequent history of the adults of the clupeoids, whose life-history from the ovum onward has here been sketched, furnishes one of the most important subjects for marine biological research in the future. Apparently all alike resort to deep water, only to return to the inshore areas as the spawning time approaches. Specimens may be occasionally captured in estuaries and inshore areas long after the usual spawning time; but their occasional character emphasizes the general rule. Like the salmon, they disappear, and their whereabouts cannot be determined. With the return of the spring or the fall spawning time the herring schools come in from their unknown haunts, just as the shad and gaspereau revisit their chosen rivers in April and May, or the pilchard and sprat congregate in their breeding areas in the open sea far out from land, the former in May, June, July and later, and the latter in the earlier summer months, though both these fish, like the smelt, come in from deep water for some unknown purpose, when they are captured in immense quantities in October, November and December; often indeed as early as the last week in September in the case of the pilchard, or as late as the third week in January in the case of the sprat. Reproduction and feeding are the two main purposes which stimulate the migrations of fishes; but these do not explain the obscure movements referred to. Even Pennant ventured to so surmise (Brit. Zoology, vol. III., 1759). Of the pilchard, he says, that 'it appears in vast shoals off the Cornish coasts about the middle of July, disappears the beginning of winter, yet sometimes a few return again after Christmas. Their winter retreat is the same as the herring, and their motives for migrating the same.' It is remarkable that fishes so familiar as these clupeoids should present problems so difficult to solve; but as Frank Buckland wrote, and the words are almost the last he ever penned: 'It will be seen that we have a huge field of inquiry before us, the results of which will not assume the form of a scientific plaything; but of a key by which we may hope to unlock the mysteries of the vast ocean.'

(In the preparation of the plates I have utilized my own drawings made from the specimens studied by me; but I have availed myself of the excellent figures published in some of the memoirs referred to in the text. These last-named figures are as follows: Plate VIII., figures 2, 3 after Mr. E. W. L. Holt, 4 after Dr. P. P. C. Hoeck; *6a, 6b* after Dr. F. Raffaele, 8, 9 after Professor W. C. McIntosh, 10 and 11 after Mr. J. T. Cunningham; Plate IX., figures 12-16 after Dr. Ernest Ehrenbaum, 17-19, 21-22 after the late Prof. Ryder, 23-25 after Dr. P. P. C. Hoeck; Plate X., figures 36-38 after Thaddeus Norris.—E. E. P.)

LIST OF REFERENCE LETTERS.

an.—anus.
af.—anal fin.
au.—otocyst or early ear.
caps.—egg capsule or zona radiata.
cf.—caudal fin.
df.—dorsal fin.
e.—eye.
int.—intestine or digestive canal.
mn.—mandible or lower jaw.
mx.—maxillary (upper jaw).
not.—notochord.
og.—oil globule.
pf.—pectoral fin.
pr. an.—pre-anal fin.
pvs.—perivitelline space.
vf.—ventral fin.
yk.—yolk.

EXPLANATION OF PLATES.

Plate VIII.

Fig. 1. *Clupea harengus.* Herring, newly-hatched larva 5 mm. x 12.
" 2. " " post-larval stage 12 mm. x 6.
" 3. " " advanced stage about 40 mm. x 2.
" 4. " " advanced stage about 46 mm. x 2.
" 5. " " $3\frac{1}{4}$ inches long. About natural size.
Fig. 6*a*. *Clupea pilchardus.* Pilchard, egg containing embryo 1·6 mm. in diameter x 25.
" 6*b*. " " newly-hatched larva, 1·6 mm. in diameter x 20.
" 6*c*. " " post-larval stage, 9th day 5·5 mm. x 18.
" 7. " " late post-larval stage 11·5 mm. x 10.
Fig. 8. *Clupea sprattus.* Sprat, newly-hatched larva 3·6 mm. x 15.
" 9. " " larva on 10th day x 20.
Fig. 10. *Pomolobus pseudoharengus.* Gaspereau, post-larval stage 15 mm. x 6.
" 11. " " later post-larval stage 16·5 mm. x 5.

Plate IX.

Fig. 12. *Clupea finta.* Twaite Shad, newly-hatched 4·25 mm. x 16.
" 13. " " post-larval stage, 6 days old 8·7 mm. x 10.
" 14. " " post-larval stage, 20 days old 14 mm. x 6.
" 15. " " advanced stage, 30 or 40 days (?) old 20 mm. x 4.
" 16. " " probably 45-50 days old 24 mm. x 3.
Fig. 17. *Alosa sapidissima.* Shad, just hatched, x 9.
" 18. " " post-larval stage, 5th day x 6.
" 19. " " post-larval stage, 17th day x 5.
" 20. " " post-larval stage, 41 mm. x $2\frac{1}{2}$
" 21. " " egg containing early embryo.
" 22. " " egg with advanced embryo.
Fig. 23. *Clupea finta,* enlarged head of, when 57 mm. long x $2\frac{1}{2}$.
Fig. 24. *Alosa sapidissima,* enlarged head of, when 61 mm. long x $2\frac{1}{2}$.
Fig. 25. Portion of egg-capsule of *Clupea finta,* showing external reticulated marking, x 240.

Plate X.

Fig. 26. *Pomolobus pseudoharengus.* Gaspereau, 30 mm. slightly enlarged.
" 27. " " 35 mm. "
" 28. " " 3 inches "
" 29. " " $3\frac{1}{4}$ inches "
" 30. " " scale from the dorsal below the base of the dorsal fin, x 20.
Fig. 31. *Clupea harengus.* Herring, scale from the dorsum below the base of the dorsal fin, x 20.
Fig. 32. *Pomolobus pseudoharengus,* abdominal scale or scute from the median ventral ridge of the body x 20.
" 33. " side view of abdominal scale or scute from the median ventral ridge of the body x 20.

PLATE X.—*Concluded.*

FIG. 34.	*Clupea harengus,*	abdominal scale or scute from the median ventral ridge of the body x 20.
" 35.	"	side view of abdominal scale or scute from the median ventral ridge of the body x 20.
FIG. 36.	*Alosa sapidissima.*	Shad, young in advanced stage 44 mm.
" 37.	"	" " " 79 mm.
" 38.	"	" " " 95 mm.

PLATE VIII

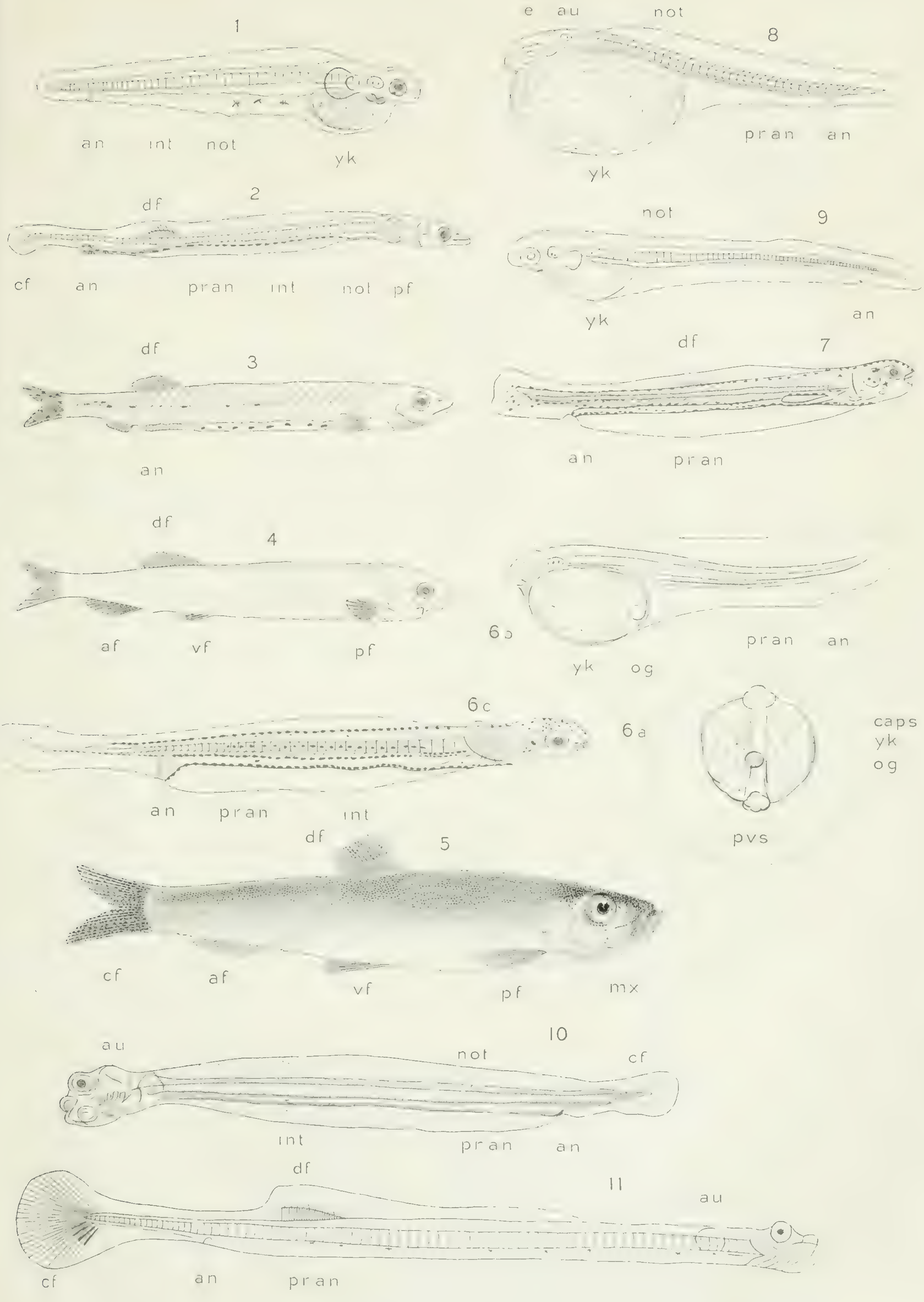
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Plate IX


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PLATE X


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XII

SAWDUST AND FISH LIFE.

FINAL REPORT BY PROFESSOR A. P. KNIGHT, QUEEN'S UNIVERSITY, KINGSTON, ONT.

The following concludes my report upon the effects of sawdust on fish life. The work was begun at the Dominion biological station, St. Andrews, in 1900, continued at the biological laboratory of Queen's University during the summers of 1901 and 1902, and concluded during the summer of 1904, by a series of observations which were made in tidal waters at different points along the coasts of Nova Scotia and New Brunswick.

LITERATURE.

Since my last report, completed three years ago, no new literature has been published on the subject in Canada, excepting in the annual reports of the Ontario Fish Commissioner for 1902 and for 1903. In his report for the former year the Ontario Deputy Commissioner of Fisheries says:—

'Ample opportunity of determining that sawdust is injurious to fish life has been given to the department while engaged in transplanting its bass, where the ice used had not been thoroughly rinsed. On an examination of the bass which had died in transmission, particles of sawdust were found between the gills, which it may be assumed caused the death of many of the fish. But the danger to and effects upon fish life from this pollution do not alone arise from this cause, but they are also due to the poisonous gases which are emitted from the decaying deposits; and these gases are not only most deadly to fish life, but they are a great menace to human health as well. It may be assumed that for this reason, in waters in the vicinity of old mill sites no fish are usually to be found.'

There are two points in this extract which require some elucidation. The first is the assumption that in transplanting bass, the fish that died on the journey were killed by sawdust. Before admitting this, one would need to know whether all the fish at the beginning of the journey were in vigorous health and strength. Can Mr. Bastedo assure us that the fish which died were not injured when they were being caught? Can he assure us that the water in which they were transported was thoroughly aerated on the journey? If not, the weaker fish and the injured fish would die from suffocation, not from the effects of a few grains of sawdust adhering to the ice. Mr. Bastedo's transportation tank may have been a veritable 'Black hole of Calcutta' for his poor bass!

The other point—that about poisonous gases— is not new to any one who possesses the slightest acquaintance with the literature of sawdust effects upon fish life.

Charles Hallock, writing in *Forest and Stream*, December 29, 1888, says:—'The old foundation walls and dams remain, and untold tons of tan bark and sawdust still cover the beds of the abandoned mill ponds, knee deep, all of it in a perfect state of preservation . . . . . . nevertheless, the brook continues fairly stocked with small trout, despite the supplementary fact that it has been unmercifully fished ever since

the days of the "Mountain Miller," fifty fingerlings per rod being not unusual now for a day's catch.'

In the same magazine a writer who signs himself 'Piscator' answers the bogy about the effects of poisonous gases emitted by sawdust. 'He discourses on the poisonous gases from rotting saw-dust, and I will not waste space in refuting this idea, so flippantly put forth from time to time, but demand that the dead fish from such causes be produced in some single river or stream in America. It cannot be done, hence full-grown men should discard such transparent nonsense.'

Another quotation. Prof. Prince, the Dominion Fish Commissioner, in his report for 1899, says:—'There is no case on record of salmon or shad or any other healthy adult fish being found choked with saw-dust or in any way fatally injured by the floating particles.'

It is to be hoped that these quotations will convince all critics that the only way to settle the question of the effects of saw-dust on fish life is that suggested by Professor Prince, namely, by 'accurate and thoroughly scientific experiments.'

In his report for 1903, Mr. Bastedo again returns to the subject. He says:—

'Referring to the injurious effects of sawdust on fish life, as to which conflicting opinions are expressed by fish culturists, a writer in a recent number of *Forest and Stream* points out that one of the first difficulties which fish culturists had to overcome in the artificial propagation of trout was the deleterious effects of the fungus growth that always appeared in the troughs and boxes in which the eggs were hatched ,especially where these were manufactured out of new lumber; and he makes the emphatic statement that this fungus is so deadly to the eggs that if a million were to be put into green lumber troughs, not a single egg mould mature. He very pertinently remarks that if the exposed surface in a hatchery trough could be the primary means of such deadly consequences, what a master power for injury there must be in sawdust, in which form the exposed surfaces of the wood are multiplied almost indefinitely. If his conclusions are well founded, the effect of throwing tons of sawdust every year upon the spawning beds, or where it will float and lodge upon the spawning beds below must be most disastrous. In his opinion, it is this fungus alone that destroys the young fish that are exposed to it, and not that mortality occurs by the sawdust becoming fixed in the gills during inhalation, as is generally supposed. Whatever ground there may be for a difference of opinion on the subject, it is well known that fish will abandon streams the beds of which have become covered with this refuse.'

The following is the letter which Mr. Bastedo has summarized in the foregoing paragraph. It is regrettable that an official should try to settle the sawdust question by quotations from an anonymous writer, rather than by the slow and accurate method of scientific experiment. Quotations may be the only contribution which Mr. Bastedo can make, but he might at least furnish the public of Ontario with quotations from some more reliable source than from a nameless writer.

SAWDUST AND FISH LIFE.

(Extract from 'Forest and Stream,' vol. 61-2, p. 490).

December 19, 1903.

EDITOR 'FOREST AND STREAM,'—Referring to the injurious effects of sawdust on fish life, will you kindly allow me to offer the following notes on the subject, from the fishculturist's point of view:

One of the first difficulties which the early trout breeders in this country had to overcome, was the presence of a fungoid growth that always appeared in the wooden troughs or boxes that the eggs were hatched in. It invariably grew on, and from the surface of, the wood that the troughs were made of, and in all our personal experience in hatching fish eggs, we never knew a single instance, east of the Mississippi, in which fungus did not appear on the surface of the wooden hatching troughs very soon after

the water was turned into the troughs, unless the wood was very old or had long been water soaked. In these cases, the fungus does not appear to so great an extent, but when the lumber is new, the fungus, except in highly oxygenated waters, invariably appears very soon after the water comes in contact with the green wood.

This fungus is one of the most deadly things in the world to trout and salmon eggs. It is so destructive that if a million trout eggs were put into green lumber troughs to hatch, they would every one of them be killed before they hatched. Not one would escape. 'Domesticated Trout,' speaking of this fungus (page 126, sixth edition), says: 'Fungus is a vegetable growth of low order, which makes its appearance almost invariably where there is water, and especially on newly cut wood, on which it eventually becomes a mass of nearly colourless or milky slime.

'This fungus, if once present in the hatching water, will certainly attach itself to the eggs, and when it does, their fate is sealed, you cannot save them from its effect, for it never lets go its hold. It will surely eat out the vitality of the embryo within, and will either kill it entirely or will leave a puny, lifeless, transparent creature, which will in all probability never live to grow up. It cannot, therefore, be guarded against with too much care.'

In consequence of this action on the surface of lumber under water, wooden hatching troughs were formerly charred, and now are all covered with a coating of asphaltum, on which fungus does not grow. No fishculturists of any experience would think for a moment of using wood for hatching trout or salmon eggs, without first covering every part of the surface with asphaltum, or something furnishing similar protection against fungus.

Now, if the exposed surface of the three planks which form the hatching trough can exercise such a deadly and universal effect on the fish eggs that are in it, what a vast power of injury there must be in sawdust, in which form the exposed surfaces of the wood are multiplied almost indefinitely. Take an inch board a foot square and reduce it all to sawdust, and it will give an amount of exposed surface almost infinitely greater than the board itself. Then consider what must be the effect of throwing tons of this sawdust every year directly upon the spawning beds of the fish, and where the sawdust will float down to the spawning beds below, if there should happen to be any below. From the moment the sawdust falls into the water it begins to produce the fatal fungus, and makes it absolutely impossible for a fish egg to hatch where it is, and what is more, the invisible fungus which destroys the eggs so effectually, gets into the gills of the young fish that are exposed to it and kills them also; and, besides this, by one of those wonderful instincts that are implanted in the lower animals, fish will avoid a stream where the conditions of spawning are unfavourable, and sooner or later will abandon a stream, the spawning beds of which are covered with sawdust.

The writer trusts that the above considerations are sufficient to show that large deposits of sawdust should be looked upon with much suspicion in streams that are valued on account of the fish life that is contained in them.

SALMO.

Of course, a fungous growth does occur upon fish eggs, but it does not necessarily come from sawdust. It is simply the case of an aquatic plant starting to grow upon organic matter—the eggs, or upon the bodies of the fry when these happened to receive injury in any way. I have seen such growths upon both eggs and fry, and that too in water that never contained a particle of sawdust. Whether this fungus is the same that grows upon rotting wood I cannot say, but of course every intelligent person nowadays knows that the rotting of all wood and trees, and the decay, putrifaction and death of animal tissues are alike preceded and caused by a fungus or bacterial growth which fastens upon the animal in the one case, or plant in the other, and ultimately causes the death of the individual.

But this fungous growth is an entirely different matter from the poisonous effects of sawdust. All wood cells, whether in the tea plant or pine, contain compounds that have been stored in the cell. When these cell contents are liberated and dissolve in

water we get a solution whose poisonous or other effects depend entirely upon the strength of the solution.

The experiments described in my second report showed clearly that the poisonous effect of sawdust water varies directly within the strength of the solution. A strong aqueous extract from sawdust is so poisonous as to kill in a short time nearly all forms of aquatic life. A weak solution is comparatively harmless. The question then of whether any particular stream is sufficiently polluted with sawdust to kill fish life is simply the question of determining whether enough sawdust has been passed into the stream to poison its waters. It is a question of the strength of the sawdust solution. There is no mystery about the matter. Any one who can understand the making of a cup of tea can understand the making of sawdust extracts. If we wish to make a strong cup of tea, we use plenty of the leaves and a comparatively small volume of water. If we wish to make an infusion we use a smaller quantity of the leaves and a larger volume of water. It is the principle which herbalists, druggists and medicine mongers have used for thousands of years. Senna tea, chamomile tea, not to speak of dozens of others, are examples of infusions such as we get by immersing sawdust in water.

Keeping this principle in mind, my work during the past summer consisted largely in ascertaining the quantity of sawdust discharged into a stream in a given time, and the total volume of water passing the mill in this same time.

The first mill visited was one located on the way to Little Harbour, a few miles from New Glasgow, Nova Scotia. The mill supplies lumber to the farmers in the neighbourhood. The timber, chiefly second growth spruce, and a little hemlock, is drawn to the mill during the winter. In the spring, when water is plentiful in the brook, the logs are sawn into boards, the sawdust and smaller refuse being discharged into the stream below.

The logs are all very small, and yield only from 40 to 100 feet per log. The total cut during the past few seasons averaged only 100,000 feet.

Previous to my visit, no rain had fallen for about six weeks, and consequently the mill was not running, on account of lack of water. The only water passing the dam was that from ordinary leakage. Below the mill, the brook was nearly dry. But in the spring and during summers when the rainfall was normal, smelt and sea trout came up to the foot of the mill dam, and were often caught with hook and line at the mill end.

The 'by-wash' at the side of the mill, by which the surplus water escaped when the mill was not running, was a very shallow flume about 14 feet wide, 80 feet long, and from 6 to 9 inches deep during the spring freshets. The total fall was 20 feet, consequently the slope down the by-wash was a very gradual one. The proprietor of the mill was of opinion that sea trout were able to pass up this by-wash and did ascend it every spring. At any rate, sea trout were caught every week by boys fishing in the mill dam. It was a common thing for boys from New Glasgow to go out to this mill pond on Saturdays and take home with them a string of trout in the evening.

Below the mill, there were none of the unsightly beds of sawdust and mill rubbish so frequently to be seen in Ontario streams. The tidal water from the Cumberland straits came up the East river, then ascended the mill stream to the very foot of the mill dam, and in returning carried away with it almost every particle of sawdust and rubbish which left the mill.

In this stream, therefore, there could be no question about the ascent of fish being stopped by mill rubbish. It was all carried down stream and away out to sea. The important question here was whether the ascent of anadromous fish was not stopped by the mill dam. If they were thus stopped, they could not reach their natural spawning grounds above. In this case, one can easily see how the supply of fish is cut off at its very source. My experiments and observations would seem to indicate that over-fishing on the one hand, and mill dams with no proper fishways, on the other hand, are

more responsible for depleting our streams and rivers of fish than all the sawdust in all the streams in Canada put together.

Applying the principle of the strength of infusions to the sawdust and water in this stream, we can soon discover whether it is poisonous or not.

The water passing the mill in the spring, when the mill is not working, is a stream 14 feet wide, 6 to 9 inches deep, and flowing at the rate of 18 inches per second. Thus 14 x ⅔ x 3/2 x 60 x 60 x 24, or about 1,209,000 cubic feet of water will pass the mill every 24 hours.

Now, as a result of very careful calculations, supplied to me by the Messrs. Todd Bros., lumber merchants, of St. Stephen, N.B., it appears that in sawing logs into one-inch and two-inch boards, about one pound of sawdust is formed for every foot of sawn lumber, board measure. On this basis, 100,000 pounds of sawdust per season would be passed into this stream, and if the mill cut timber for 100 days per season, about 1,000 pounds of sawdust would be mixed with the 1,209,000 cubic feet, or about 75,000,000 pounds of water. Expressing the sawdust in the form of percentage, we find the solution would be ·001 of 1 per cent.

Turning now to my laboratory experiments,* we find that a strength of ·12 per cent killed a minnow in 20 minutes, and a percentage of ·16 per cent killed a minnow in 90 minutes. That is, the pollution in this stream was only 1/120 of the strength of the laboratory solutions. Of course, these figures are only approximations, but they point unmistakably to the conclusion that this small mill stream emptying into the East river and thence into Pictou harbour, is not polluted with sawdust sufficiently to kill fish life.

The next mill I visited was one on a branch of the Petitcodiac, a river which flows into the Bay of Fundy. The proprietors gave me the following information: The quantity of lumber that is cut ranges from thirty to forty thousand feet per day, during a season of five months, say 4,500,000 feet of lumber. The stream in high water is about 220 feet wide, and from 5 to 6 feet deep. The average velocity is 2 miles an hour. In August, when I was there, the stream was only about 50 feet wide, and the depth did not exceed 12 or 15 inches. Consequently, if we average these estimates it will be found that about 700,000,000 pounds of water would pass the mill every 24 hours. The sawdust, at the estimate of 1 pound for every foot of lumber cut, would amount to 35,000 pounds per day, or expressing these figures as percentage strength of solution, about ·05. Here, again, therefore, there can be no doubt that sawdust does not kill fish life. But, here again, there are mill dams upon the stream with no proper fishways, and consequently anadromous fish cannot pass up to their spawning grounds. Add to this the fact that this and similar streams are all overfished year after year, and the amazing thing is that any fish are left in them at all.

AT ST. JOHN, N.B.

On arriving at St. John, I visited a number of the lumber mills and obtained a vast amount of information from a member of one of the largest lumber companies in the city. The annual cut of each firm, the kind of saws used—whether gang, band, or circular saw—and the mode of disposal of the refuse, were all carefully discussed. None of the mills in the immediate vicinity of St. John empty the sawdust into the river, but a few large mills and a considerable number of small ones far up the river and its branches, do discharge the sawdust and other refuse into this stream.

While, therefore, little refuse in the shape of slabs, edgings, butt ends, or bark, could be seen for many miles up the river, and no trace whatever of sawdust; yet, gradually, as I reached a part nearly halfway to Fredericton, there appeared evidence of the work of the lumber mills. Edgings, laths, logs, and sawdust were seen either floating or stranded plentifully along the shore. Opposite and above Maugerville this was

* See my 'Further Report' to Minister of Marine and Fisheries, published, 1906.

specially the case. The commonest kind of logs were spruce and cedar, and mingling with these a few pine.

In the upper half of the journey to Fredericton, a number of small sawmills were noticed here and there along the shore. Evidently they were doing a purely local trade. Quite a number had been abandoned. Nine miles from the capital there was brisk rafting of logs, no less than four steam tugs being employed in this work. The booms and logs extended for 4 or 5 miles along the river. All the mills along this part of the river were driven by steam and burnt their own sawdust.

Between St. John and Fredericton, therefore, there is no doubt that neither the rubbish nor the sawdust exists in sufficient quantity in the river to do any harm to fish life. But it becomes a matter of interest to ascertain, if possible, what the effect would be if the refuse from all the mills at St. John and up the river did discharge their sawdust, slabs, edgings, &c., into the stream. Because it must be remembered that up to 1899 the law against discharging mill rubbish was not enforced upon the St. John river, and certain other large rivers in Ontario and Quebec, inasmuch as parliament thought it only fair to the lumbermen to allow them the privilege of getting rid of their waste lumber in the easiest possible way.

Assuming then, that mill waste were discharged into the St. John river, what would be the effect? If it would poison fish eggs, fish fry, or the minute microscopic life which forms the food of fish fry, we can easily understand that this would be one reason why fish have decreased in number in this river during the past 30 or 40 years. Let us see. According to the information I received from lumber merchants in St. John, the following is a fair estimate of the cuts of lumber on this great river during the last year or two:—

	Feet, board measure.
Messrs. Burns & Murchin	10,000,000
" Hilliard Bros.	10,000,000
" J. R. Warner & Co.	10,000,000
" A. Cushing & Co.	43,000,000
" Murray & Gregory	15,000,000
" Stetson, Cutter & Co.	30,000,000
" Randolph & Baker	20,000,000
" Dunn Bros.	10,000,000
" John E. Moore	10,000,000
" Miller Bros	23,000,000
M. A. Gibson	40,000,000
The Scott Lumber Co.	10,000,000
Messrs. Murchin & Sons.	5,000,000
R. A. Estey	7,000,000
A. Fraser	10,000,000
Tobique Lumber Co.	10,000,000
Van Buren Lumber Co.	13,000,000
St. John Lumber Co.	33,000,000
Geo. Murchin	8,000,000
A number of smaller mills on the St. John and its branches in Canada and the United States	90,000,000
	407,000,000

Now, on the assumption that each foot of lumber, board measure, will produce a pound of sawdust, the total sawdust would of course amount to 407,000,000 pounds per annum.

So much for this part of the data required to find the strength of the sawdust pollution of the St. John.

According to the Hydrographic Survey of the State of Maine (Walter Wells, superintendent, 1869), the total drainage area of the St. John river is 26,000 square miles, of which 7,400 lie in the State of Maine. The annual discharge from the area in Maine is 284,000,000 cubic feet. Using this as a basis, it follows that the annual discharge from the whole area will amount to about 1,000,000,000,000 cubic feet, or 62,000,000,000,000 pounds.

On the assumption that the saw mills run for about two-thirds of the year, say 200 days, it will follow that 407,000,000 pounds of sawdust mingle with about (40 trillion) 40,000,000,000,000 pounds of water. Expressing this in the form of percentage strength of sawdust solution, we get ·001 as the result.

Comparing this again with my laboratory experiments, in which a solution of ·12 per cent strength killed a minnow in 29 minutes, and another solution in which a strength of ·16 per cent killed in 90 minutes, we see that even if all the mill refuse were discharged into the St. John the pollution would not be great enough to kill fish.

Moreover, we must make two allowances in the case of the St. John river. In the first place, much of the lumber is spruce, and according to my laboratory experiments of 1902, spruce sawdust was the least poisonous of all. In the second place, it must be remembered that St. John is the scene of the great reversible falls. During two periods of every 24 hours the St. John river falls into St. John harbour. During two other periods of the day the salt water of the Bay of Fundy pours into the mouth of the St. John river, the tide effects being felt as far up the river as Fredericton. This immense body of salt water, therefore, mingling with the fresh water of the river, lessens the strength of the sawdust pollution at the mouth and renders it still less likely to do harm.

BAY OF FUNDY.

One would suppose it quite as likely to hear that the Atlantic was polluted with sawdust as to hear that the Bay of Fundy was. And yet that is precisely what could be heard among the fishermen along the Bay of Fundy in 1877 and 1879.

In 1889, the late W. H. Rogers, inspector of fisheries, published what was known as *The Suppressed Sawdust Report*. Writing in reference to pollution of the Bay of Fundy, he says (page 2 of his pamphlet):—

'It has been stated that the falling off in the catch of shad in the Bay of Fundy was caused by sawdust; that fish swallowed it, and died in large numbers in consequence. The fact that ideas of this kind gained some credence led me to inquire more carefully into the matter, but not for my own satisfaction, because no such doctrine could be accepted by any one with the most limited knowledge of the habits of fish, or the natural laws governing them. The same idea had been exploded several times before in the case of other branches of the fisheries, notably the Digby herring fishery. My views and reports on this fishery will be found on file in the year 1879, and it will be seen that the state of that fishery since has fully sustained the position I maintained at that time. The average annual catch from 1870 to 1879, ten years, was 22,300 boxes, and from 1880 to 1887, eight years, 55,200 boxes. During the years 1877 and 1879, when the annual catch fell to about 5,000 boxes, sawdust was pointed to as the cause, and numerously signed petitions were sent to the government pressing for the enforcement of the law. My view was stated to be that the decrease was merely owing to a periodical fluctuation, with which sawdust had nothing to do, and that the fish would return in as great abundance as ever. And I appeal with full confidence to the facts, as stated, substantiating my view after an experience of nine years has thrown its light upon the subject. In 1887 the catch of Digby herring amounted to 74,135 boxes; the catch for 1888 is only 12,200. We may, therefore, expect again that large numbers of petitions will be sent to the government asking the enforcement of the sawdust law, so as to save the Digby herring fishery from destruction.'

THE STE. CROIX RIVER.

Returning again to the immediate subject of my report, I would like to call special attention to the conditions found at St. Stephen, N.B., on the Ste. Croix river.

This river has been the scene of lumbering and milling operations, I suppose, for over a hundred years. At first the trade was an export one with the mother country, the lumber being in the form of square timber. The many old wharfs at St. Andrews now in a state of utter decay may be taken as an index of the extent of these early lumbering operations. That a great deal of wealth was accumulated in these early days, both at St. Andrews and St. Stephen, from the trade in timber, is attested also by the remains of many fine private residences and grounds still to be seen in every street of these towns, but especially in St. Stephen.

Gradually, as the character of the lumber trade changed from the manufacture and export of square timber to that of deals and boards, the centre of this business shifted from St. Andrews to St. Stephen, because here there was magnificent water power. At one time—some thirty years ago—there were not less than 13 large sawmills at St. Stephens, all discharging every pound of their sawdust into the Ste. Croix river. To-day there is not one-third of this number. The sawdust is still discharged, however, into the river, excepting that from cedar shingles, which is carted away and burnt.

During the many years that sawing has been carried on here, millions of tons of sawdust must have been passed into this river. When the tide is out, the sawdust is carried down below the town by the river's current, so that for practically a mile below, little or no sawdust accumulates along the banks. But beyond this point, for a distance varying from 1½ to 3 miles, immense beds form, especially during July, August and September, when the water is low in the river. During the freshets of spring these beds are washed down and away out into Passamaquoddy bay.

Here then, if anywhere in Canada, we ought to find fish killed by thousands as a result of the fungus growths, poisonous gases, or other effluvia which have been so graphically described by those who have written upon the ill-effects of sawdust. But, strange to say, so far as I can learn, no unusual death rate among fish has ever been reported along the mouth of the Ste. Croix. On the contrary, there has been only the usual decrease in the catch of anadromous fish, such as has occurred along almost every river in the maritime provinces. The decrease has not been due to the effects of sawdust, but to deforestration, to overfishing, and to lack of fishways, or improper fishways, so that anadromous fish cannot pass up the rivers to their natural spawning grounds.

Moreover, Mr. Frank Todd, an unusually well-informed man upon all fishery matters, a gentleman who has been inspector of fisheries for this district for a number of years, tells me that he has caught hundreds of salmon at the tail end of the lowest mill on the river, where sawdust would naturally be most abundant; and that during every season for years he has watched salmon ascending the river towards their natural spawning grounds above.

Looking at the mills, the sawdust, the fishways and the annual catch of salmon by anglers, it is quite clear that sawdust has not destroyed the salmon fishing on the Ste. Croix river.

Turning now to look at the subject from the point of view of an infusion of sawdust in water, what do we find? Well, we find this: The annual cut of lumber at St. Stephen, board measure, is, according to Mr. Frank Todd, about 35,000,000 feet. According to Mr. Wells, from whose report I have already quoted, the annual outflow of water of Ste. Croix is 44,800,000,000 cubic feet, or, expressed in pounds, 2,800,000,000,000.

Now, if we express the weight of sawdust as percentage of the weight of water for two-thirds of the year, which is about the length of time that the sawmills run each year, we shall find that the solution is one of ·002 per cent strength.

Comparing this with fatal doses of sawdust poison as determined in my laboratory experiments already alluded to, it can easily be seen that no harm can be done to fish fry or fish eggs by the water at the mouth of the Ste. Croix river.

Moreover, another important factor must be taken into account. Tidal water rises about 3 feet at the ends of the lowest mills on the Ste. Croix. The sawdust is discharged, therefore, not into 123,000,000 cubic feet of river water daily, but into this amount of fresh water plus the tidal water of Passamaquoddy bay. This tidal water is of immmense volume. When the tide is out the river averages 50 yards in width and four feet in depth for 5 miles below the mills. When the tide is in, this increases to 150 yards in width and 20 feet in depth. In other words, the volume of water into which the sawdust is discharged becomes fifteen times larger, and the strength of the solution becomes fifteen times less. Consequently, in tidal waters sawdust pollution is diminished and the poisonous effects, if any, are still further reduced below what they would be in a river that did not discharge into the sea.

CONCLUSIONS.

1. I submit the same general conclusion as I did in my report for 1902. No stream can be pronounced off-hand as poisoned by sawdust. Each stream must be studied by itself and the varying conditions must be thoroughly understood before a judgment can be pronounced. The chief things to be considered are (1) the quantity of sawdust and (2) the volume of water into which the sawdust is discharged. Subordinate conditions are the rapidity or sluggishness of the stream, the amount of sunlight or shade and the character of the water, whether from agricultural lands or from primitive forests.

2. I have not the slightest hesitation in saying that no stream or river which I have yet studied in Ontario, New Brunswick, or Nova Scotia, is sufficiently polluted with sawdust to destroy half grown or full grown fish.

3. The varying strengths of sawdust solutions that will kill different kinds of fish eggs have not yet been determined. Perch eggs were hatched out in the university laboratory in a solution of ·03 per cent strength.

4. In place of sawdust being the potent factor in the destruction of fish life, it would seem likely that mill dams are the real cause. Mill dams without proper fishways prevent the ascent of anadromous fish to their natural spawning grounds, and thus cut off all chance of natural propagation. As suggested in a recent report by Professor Prince, the question of the adequacy of fishways is a vital one to Canadian fisheries.

5. It would seem more reasonable to amend the Act against passing sawdust into streams, and make it approximate to that in force in the State of Massachusetts. In this state, it is provided that whenever the Fish and Game Commissioners should decide 'that the fish in any brook or stream are of suficient value to warrant the prohibition or regulation of the discharge of sawdust from sawmills, and that the discharge thereof from any particular sawmill materially injures such fish, they could restrict the pollution by an official order.'

This would compel a personal inspection of a stream before an order could be issued to stop its pollution by sawdust. In this way both the interests of millowners and of the general public would be carefully weighed before the law would be placed in execution.

XIII

PROFESSOR MACALLUM ON THE CHEMISTRY OF MEDUSÆ.

A CONDENSED RÉSUMÉ OF RESULTS

By Professor Edward E. Prince.

Commissioner of Fisheries and Director of the Marine Biological Station of Canada.

A detailed account of the laborious researches of Professor Macallum, F.R.S., on the inorganic composition of certain marine jelly-fishes or medusæ, appeared in the *Journal of Physiology,* Vol. XXIV., pp. 213-241. These researches were commenced in the summer of 1900, at the Marine Biological Station of Canada, and were continued during several seasons, with results so interesting in themselves and so suggestive in their theoretical bearings as to justify repetition in an abbreviated popular *résumé.* The conclusions which they appear to reasonably yield are, indeed, of such profound biological significance that I have ventured to prepare a condensed summary, divested as far as possible of technical phraseology.

The medusæ are amongst the most familiar of sea-side objects. These disc-shaped *Cœlenterates,* variously called jelly-fishes, sun-fishes and sea-nettles are, as Dallas said, 'wonderfully beautiful creatures, though the amount of solid matter contained in their tissues is incredibly small. The greater part of their substance appears to consist of a fluid differing little, if at all, from the sea-water in which the animal swims, and when this is drained away, so extreme is the tenuity of the membranes which contained it, that the dried residue of a jelly-fish, weighing two pounds, which was examined by Professor Owen weighed only thirty grains.'* The fluid or so-called jelly substance is, however, as Professor Macallum's researches show, not identical with sea-water. Professor Macallum began his investigations by placing jelly-fishes in vessels of sea water of various strengths, and by altering the proportions of individual salts, he endeavoured to ascertain the action of the salts upon these living organisms. As the exact composition of the jelly-fishes themselves was unknown, it soon appeared to him that no conclusive results were possible until the composition of the medusæ had been ascertained. Two species, it may be mentioned, were specially studied, viz.: *Aurelia flavidula,* Peron and LeSueur (closely allied to the European *Aurelia aurita*) and *Cyanea arctica,* the first-named ranging from 5 to 10 inches in diameter, in the late summer months when it is mature, while the last-named (*Cyanea*) may reach a size of 3 to 5 feet across the disc, although smaller examples are most common. Specimens of *Cyanea arctica* are on record having a diameter of not less than 7½ feet, and possessing tentacles over 120 feet long.†

Owing to their simplicity of structure, especially their histological features, there is a prevalent impression that jelly-fish imbibe, in sponge-like fashion, any fluids by which they may be surrounded, and Professor Loeb, of Chicago, has published the opinion that the existing chemical environment normally affects directly, not only the chemical constitution of medusæ; but their physiological activities as well, to a remarkable extent. The swimming motions or pulsations of *Aurelia* and *Gonionemus* are dependent, he declared, upon the presence of sodium, calcium, and potassium ions in their sea-water environment. Professor Loeb instanced an experiment in which a ring-like portion of the margin of *Gonionemus* was cut away, and the usual locomotor pulsations ceased in ordinary sea-water; but, when placed in a $\frac{5}{8}$ normal solution

*Natural History of the Animal Kingdom, London, Griffin & Co., p. 70.
†Rolleston's Forms of Animal Life. 2nd Ed., Oxford, p. 788.

(i.e. 3·6 per cent) of sodium chloride, it rythmically contracted for an hour or more. He decided that the margin differed from the centre of the disc in that species, and contained sodium, calcium and potassium ions in different proportions. The pulsations in the case of *Aurelia* did not cease after its margin had been cut off. Dr. Macallum found, however, that the contractions of the disc of *Aurelia* were rare and feeble in ordinary sea-water, after cutting away the margin of the disc, though very vigorous in the $\frac{5}{8}$ normal solution of chloride of sodium; but he concluded that the salts did not act directly on the tissues, e.g., the nerve cells, muscles, &c., as Dr. Loeb thought; but on the nerve endings in the epithelium of the lower surface of the jelly-fish, usually called the sub-umbrella. This was clear from the fact that all contractions ceased when a 0·08 per cent solution of formalin in sea-water was gently brushed over the surface, or when the surface was so stroked with the back edge of a scalpel as to scrape the epithelium. These ectodermal cells, or epithelium elements, which form the thin covering over the gelatinous bell (mesoglœa) possess no markedly contractile character, and have assumed, in the morphologist's view, a function practically sensitive and protective alone, 'they have largely given up,' as the late Professor T. Jeffery Parker said, 'the function of contractility to the muscle processes or fibres.' This layer of living ectoderm prevents that direct influence, and interchange, which Professor Loeb regards as exercised by the chemical environment of the medusæ. Any rapid exchange between the outside medium and the salts in the tissues of the jelly-fish is barred, otherwise the composition of the 'jelly,' which forms so large a portion of the disc, would change with every change in the sea-water in which the creature floats, e.g., in passing from ocean water to brackish, and *vice versa.*

The gelatinous tissue or jelly is really a supporting lamella between the endoderm and ectoderm layers, but immensely thickened, as compared with the mesoglœal lamella in *Hydra,* and it is very effective in impeding the exchange referred to, and indeed, in preventing the diffusion of foreign matters. Methylene blue, injected by a hypodermic needle into a vigorously pulsating *Aurelia*, was found to stain one spot only, and it was not possible to detect any spreading-out of the colour even after 24 hours interval. While the prevention of the diffusion of foreign substances is secured on the one hand, and the retention, on the other hand, is ensured of fluid and inorganic matters, the loss due to injury is also minimized and repairs to the surface are facilitated, even when such injuries are extensive. Thus, a third of the disc may be removed; but the naked cut surface is soon overgrown by a cuticle of small and glistening epithelium cells. The jelly consists of a minutely reticulated meshwork of proteid, called discin, which retains water and inorganic salts, and by its excessive firmness resists diffusion and osmosis so long as the trabeculæ are maintained. Though the epithelial cuticle interposes a barrier against rapid exchange between the watery environment and the disc substance, and the mesoglœa itself resists the diffusion of foreign matters, yet the epithelial cells of the surface of the bell, and the lining cells of the gastro-vascular canals, exercise a remarkable selective power. They take in some chemical matters and reject others in the most unmistakable manner.

Before referring to the details of this interesting selective action of the cells as living units, and to the methods adopted by Professor Macallum in his researches, it may be necessary to point out that the composition of medusæ has engaged many observers. Krukenberg found in *Rhizostoma Cuvieri*, from the Adriatic, that the solids were 4·608 per cent and the organic 3 per cent; in *Aurelia* the solids were 4·2056 and 4·66 per cent, and in *Chrysaora hyoscella,* the percentages of solids were 4·25 and 3·7. Ladenburg found in two examples of *Aurelia aurita* from the Bay of Kiel, where the surface salinity is 1·7 to 1·8 per cent on the average, that the solids were 2·06 in one example, and in another 2·1 per cent. Krukenberg also attempted the estimation of the chlorine in medusæ from different localities, and found that *Aurelia* from east of the mouth of the Rhone showed 1·5975, and *Rhizostoma Cuvieri* showed 1·65075 per cent, as compared with specimens of *Aurelia* from the Gulf of Trieste and the Red Sea, which showed a percentage of chlorine as follows: 1·79275, 2·0306 and 2·2223, when

the water of the sea contained respectively, chlorine percentages as follow: 1·8105, 1·931 and 2·0945. Other medusæ, from the same sources, Krukenberg found to contain chlorine greater in amount than in the surrounding sea-water, and he stated that in medusæ from waters of low salinity, their salinity was relatively much higher than in medusæ from sea-water of high salinity. He also found that a piece of jelly (in sea-water of 2·1868 per cent of chlorine) gave a fluid containing 2·334 per cent of chlorine; while, when the sea-water contained 2·272 per cent, the jelly fluid showed 1·345 per cent of chlorine—a most remarkable result, due to diffusion laws. Whether the loss of water, however, was owing to exudation or to mechanical processes, Krukenberg could not decide. In distilled water pieces yielded, he found, 4·93 and 4·13 per cent of chlorine, and in a medium containing magnesium sulphate only, the loss of salts decreased with the increase in the strength of the sulphate. A 6 per cent solution showed 4·33 per cent in the fluid given off, while in a 10 per cent solution it was 4·34 per cent; but in a 20 per cent solution the chlorine in the fluid was 3·229 and 3·666. With solid magnesium sulphate placed on the fragment of jelly, the fluid given off contained from 1·292 to 1·596 per cent of chlorine.

For the purposes of the St. Andrew's investigation it was necessary to have ample material to enable adequate analyses to be made. Hence a juice was prepared from living specimens of jelly-fish. The specimens were suspended in muslin bags in the station laboratory, for about ten minutes, so that the sea-water on the outside, and in the gastro-vascular canals internally, could drip away.

After this draining the specimens of *Aurelia* were subjected to a mincing process by hand, and the fine minced jelly was, after a second straining, kneaded thoroughly until liquified. The strained fluid, mixed with the kneaded material, presented a turbid appearance until the cellular elements settled, when the liquid was opalescent. Crystals of thymol were used for preserving samples, or else 2 cc. of formalin to 1000 cc. of the fluid. This fluid was stored in phials having tight-fitting glass stoppers.

As the canals in *Cyanea arctica* continue into the long dependent filaments, more time was necessary for the draining process in that species; but even after the lapse of an hour some sea-water still remained. There was in consequence of longer suspension some loss of organic material.

The specimens of *Cyanea* were then allowed to liquify spontaneously, after being broken up, and in the course of twenty-four hours a brownish red liquid resulted, in which the ropy tentacles remained undissolved. This was preserved by adding 2 or 3 cc. of formalin to 1000 cc. of the fluid. Preservation was satisfactory, but a precipitate settled in the *Aurelia* fluid, consisting largely of magnesium hydrate in union with some proteid matter. The medusa fluid or juice was subjected to elaborate analysis by Professor Macallum in the physiological laboratories of the University of Toronto, and the details require, of course, to be studied in the original paper, but the main results may here be summarized:—

(*a*) The sulphuric acid is much below that of the surrounding sea-water, absolutely and relatively.

(*b*) The magnesium is less than in sea-water, in *Cyanea* as much as 10 per cent less.

(*c*) The lime is the same as in sea-water at St. Andrew's and Canso in the case of *Aurelia;* but in *Cyanea* it is greater.

(*d*) The potassium shows the greatest disparity, being in *Aurelia* 40 per cent in excess of the amount in the sea-water and in *Cyanea* 100 per cent greater.

The selective action of the living cells forming the exterior covering and the internal (gastro-vascular) lining, is responsible, there can be no doubt, for the relatively large amount of potash salts taken in, and the ratio of the proteid nitrogen and phosphorus in one as compared with the other, viz., 1:2·5 is corroborative. The slight decrease in the sodium may be due to its replacement by potassium. The difference of the aqueous environment at St. Andrew's and at Canso explains the difference in the analyses of the specimens of *Aurelia* from the two places. Their subjection every

twenty-four hours to greater variations at St. Andrew's than at Canso during embryonic and larval life is the likely explanation. At St. Andrew's the extremes are no doubt in April and August, but at Canso the range of variation is limited, and due to the depth, &c., of the adjacent waters. The following chlorine determinations show this:—

Surface water, Canso, chlorine 1·6543.

Atlantic outside of Canso, chlorine, surface, 1·6032 ; 10 fathoms, 1·6302 ; 25 fathoms, 1·7262 ; 50 fathoms, 1·7476.

The degree of salinity in the surrounding medium affects little the presence of chlorine in medusæ. If once a salt of sea-water is appropriated by the jelly, it remains there for life, and any exchange must inevitably be slow. The jelly favours fixity and uniformity of concentration, and the epithelium cells are effective as a barrier. Professor Macallum's view is that heredity must be the cause of the selective power, whereby the cells accept the lime and sodium salts on the whole as they are in sea-water, and take in also the potash, but reject some of the magnesium and sulphuric acid. Whether, however, a power of choice was inherent from the first in medusæ, or developed as an acquired function, must be decided by the conditions regarded as obtaining in their ancestral progenitors, and the sea-environment in which they existed in past geological times.

Cœlenterates are a primitive type, indeed, the *Graptolitidae* of the Silurian age, and the Silurian and Devonian *Stromatoporida*, are generally regarded by palæontologists as hydroids, and there can be no question of the remains of Jurassic medusæ in the Solenhaufen slates, and of at least one Cretaceous medusa; and the reference of these ancient forms to the order of (Craspedote) Trachymedusæ, and to certain orders of the *Acraspeda,* shows a striking stability in their morphological and structural features.

What must have been the environment of the early jelly-fishes? What were the surrounding conditions in the primitive seas which determined for these ancestral Hydrozoans that fixity of inorganic composition referred to? Professor Macallum points out that the primal seas, when life first appeared, must have contained a less quantity of salts, derived from the more readily decomposable rock materials, under the enormous atmospheric pressures, and at the high temperatures, at which vapour condensation first took place.

Biologists are well aware of the fact that the simplest forms of animal life (such as the Protozoan form *Amoeba*), while intolerant of extremes of heat, become sluggish as the temperature rises above 15° C. until at 30° or 35° C. movements cease altogether, but may be restored by lowering the temperature. If, however, the heat be raised to 40° C. heat rigour is produced, the protoplasm coagulates and the organism dies. There is, of course, a certain percentage of salts in solution in the fresh water in which *Amoeba* lives.

The sudden addition of 2 per cent of the chloride of sodium at once produces dry-rigor and general shrinkage; but if the change be gradual *Amœba* will live in a 4 per cent solution, i.e., one twice as strong as that which results in dry-rigor, if the change is sudden. *Amœba* has no barrier-membrane or cellular layer, but merely an ectosarc or slightly differentiated protoplasmic stratum externally. The contrast between the Protozoa and the Metazoa renders deductions unsafe, but, after all, Medusæ are low in the scale. Experiments with a remarkable fresh-water Medusa (*Crapedacustas sowerbii* Allm.*) discovered in the Royal Botanical Society's Gardens, Regents Park, London, some years ago, are interesting in this connection. Marine Cœlenterates are not very tolerant of fresh-water, and the Medusa just mentioned is the only non-marine jelly-fish known. Romanes found that it was even more intolerant of change. Dropped ino sea-water at 85°F. (being a tropical species) it remained unaffected for 15 seconds, then there were two or three tonic spasms, lasting

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*Professor Ray Lankester named it *Limnocodium* at the time of its discovery. See *Nature,* Vol. XXII., 1880 (pp. 147, 177, 361, &c.).

a few seconds, but in 30 or 40 seconds these faded into irregular twitchings. It became contracted and quiescent at the end of the first minute. On being replaced in fresh-water a strong spasm occurred after five minutes had elapsed, and for 20 minutes there was no motion. Irritability continued for some hours, as proved by pinching with forceps, but the effects of the sea-water immersion proved fatal. It was found to live for some hours in brackish or very weak salt-water (1 in 12, or 1 in 15), and it lived for days in a still weaker solution (1 in 18). Marine jellyfish cannot endure a high temperature, indeed 70°F. is fatal; but this fresh-water form withstood 100°F.—its pulsations being 80 per minute at 65° to 75°F., while they increased to 130 per minute at a temperature of 85°F. Freezing killed *Crapedacustas,* whereas marine species have been frozen and on being thawed out, they swam about as usual. Again, marine species survive for hours in saturated brine, as Romanes proved. There is a parallelism, as Dr. W. B. Carpenter long ago pointed out between morphological differentiation and physiological differentiation, and the physiologist may well be impressed by the diverse animal forms, amongst the Metazoa, which are able to maintain a vigorous vitality in the midst of greatly changed or changing external conditions. They have within themselves the power of compensating for these changes in an extraordinary degree. Above all, the specialized and complex organization of man possesses surprising capability of resistance to, or rather, independence of, environmental changes. He is capable 'of sustaining the highest as well as the lowest extremes of temperature and of atmospheric pressure,' to quote from the distinguished authority just referred to. This resistance to varying external changes, is an inherent potency by which organic individuality is to no small extent maintained.

To return from this excursus to Professor Macallum's investigation, it seems clear that while the inorganic composition of *Aurelia* and *Cyanea* has acquired comparative fixity, the adaptation of these forms to changes in chemical environment is incomplete and variable. When the salts in sea-water were less abundant than they are now the medusæ would, doubtless, acquire a fixed relation to the relatively concentrated potash salts, while more tolerant of the salts of soda, as they became more concentrated. More than the usual amount of potash salts would be absorbed, in order to retain the physiological equilibrium; but this excess would diminish as the cells accommodated themselves to the altered relation between the potash and the soda salts. The power of taking up sodium and magnesium compounds would increase though not to such a degree as to take in the full amount present in sea-water. Further, the power to select lime would early approximate to the limit of the amount in sea-water.

The amounts, absolute and relative, are detailed in the following table:—

a. ABSOLUTE AMOUNTS IN 100 PARTS.

—	Sp. gr.*	Cl	SO_3	CaO†	MgO†	K	Na	Total Salts.
Sea water, St. Andrews—April...	1018·03	1·347	0·15126	0·04105	0·14888	0·027184	0.74236	2·41704
" " August..	1023·79	1·7473	0·20257	0·05259	0·19344	0·035395	0·988235	3·16566
Aurelia, St. Andrews....	1023·49	1·7174	0·13363	0·0515	0·17556	0·048745	....	....
Sea water, Canso—△= −1·825° C.	1022·78	1·6543	0·18931	0·04943	0·18377	0.033503	0·91898	2·98264
Cyanea, Canso—‡△= −2·137° C..	1024·42	1·6842	0·11349	0·048785	0·16946	0·068935	0·89926	2·9279
Aurelia' Canso—‡△= −2·01° C...	1023·52	1·7231	0·12245	0·05375	0·18205	0·048103	0·928773	3·00175

* As compared with distilled water at 4° C.

† Given as CaO and MgO to facilitate comparison with the tables of Dittmar and Forchhammer.

‡ Cryoscopic determinations on carefully filtered juice in each case.

b. AMOUNTS RELATIVE TO CHLORINE (Cl=100).

—	SO_3	CaO	MgO	K	Na	Total Salts.
Sea water, St. Andrews—April	11·23	3·04	11·06	2·018	55·12	179·44
" " August	11·59	3·001	11·07	2·025	55·82	181·1
Aurelia, St. Andrews	7·77	2·998	10·22	2·838	....	....
Sea water, Canso	11·44	2·988	11·11	2·032	55·55	180·3
Aurelia, Canso	7·11	3·118	10·56	2·792	53·9	174·2
Cyanea, Canso	6·73	2·89	10·06	4·093	53·38	173·84
Ocean water, Mean (Dittmar)	11·576	3·026	11·21	1·997	55·27	180·584
" " " (Forchhammer)	11·88	2·95	11·03	1·602	....	181·1

That the amount of sulphuric acid is much below that in sea-water, both absolutely and relatively in *Aurelia* and *Cyanea,* is very noteworthy, and its slow rate of increase in sea-water must be the explanation of the low proportion. There are three equivalents of acid to one of lime in sea-water; but in river-water the acid equivalents are much smaller than those of the lime. Apparently it was not possible for the Medusæ to accommodate themselves to these external constituents in the same degree, owing no doubt to the physiological rate of accommodation being slower for sulphuric acid. The degree of accommodation to each constituent of sea-water varies very much, resulting in a deficiency in the case of sodium of 3-4 per cent, of magnesia 5-10 per cent, and sulphuric acid 32-36 per cent.

While these speculations are offered by Professor Macallum with reserve, they give interest to the well-known fact that some salts are relatively more abundant in their vascular fluids than in the media in which animals live, or than in their food.

The proportions of sodium, calcium and potassium, omitting for the moment magnesium, in the *Aurelia* and *Cyanea* juice, are strikingly similar to their proportions in mammalian serum and in Ringer's solution*, and indicate that these proportions in plasma are primitive and ancestral, and must date from a geological epoch when sea-water was poorer in salts of magnesia than it is now. In vertebrates and invertebrates of old, as in the Medusæ of to-day, the fluids in the vascular system might be compared to modified sea-water, so far as its inorganic constituents are concerned, and the physiological relation between the tissues and the salts in their vascular fluids, fixed primitively, continued hereditarily to their descendants, whether they changed their habitat from the sea to fresh-water or to the land. The low proportions of magnesium to sodium in vertebrate blood, and the high proportions in sea-water, must have been established when magnesia was less abundant than now in sea-water.

The view propounded by Professor Macallum implies that in the sea originated all animal life. 'The sea,' August Weissmann indeed declared, 'is the birthplace of all animal and plant life; and from it animals and plants have spread on to the land and into the fresh waters which permeate it.'

The jellyfish tissues have, it is clear, accommodated themselves to the high and increasing magnesium content of the ocean. Professor Loeb's idea that sodium ions are poisonous in sea-water, and may be antagonized by calcium and potassium ions in the tissues, mistakes and obscures the significance of the problem. The animal cell, exposed for ages to the three elements in its environment, has adapted itself to them, and the proper explanation of the third element's action is, that such a mixture of the solutions reproduces the primitive fluid-environment of the creature, hence the terms 'poison' and 'poisonous' are inapplicable.

*Ringer's solution is a mixture of salts favourable for the development and maintenance of contraction in cardiac and ordinary striated muscle.

The physiological habit, established ancestrally, is maintained. Loew's idea that, because potassium salts favour chemical condensation-processes, this accounts for the high selective capacity for potassium possessed by animal and vegetable organisms, fails, however well-founded, and does not explain why medusa cells pack such salts away in the inert or dead jelly of the bell.

Reference may be made to other salts, small in quantity but important, and conveniently omitted in estimating the total sum of salts in sea-water and in the juices of medusæ. There is apparently no alumina in *Aurelia* and *Cyanea,* while the silica detected is so small in quantity that it may be due to sand particles, protozoan skeletons, &c., in the gullet and gastro-vascular canals, though the jelly of *Aurelia* may contain silica, as sponges and cœlenterates, of course, can utilize the silica of sea-water. The iron present is, in St. Andrew's *Aureliæ,* ·0036 to ·004 per cent, and in Canso *Aureliæ* ·00087 (volumetrically), while in Canso *Cyanea* it is ·001796 to ·00207 per cent, whereas St. Andrew's sea-water contains only ·00006 per cent and Canso sea-water slightly more, viz.: ·00098 per cent. Phosphoric acid in *Aurelia* juice contains ·013314 per cent and *Cyanea* juice ·030315 per cent, but it must be noted that only a small portion exists in inorganic combustion, the rest being from nucleo-proteid and lecithin. Bromine in sea-water, according to the late Professor Dittmar, is ·3402 of the total halogen, and in *Aurelia* from Canso, with a total halogen of 1·723, it would be ·00586 per cent. Iodine, in 50 litres of sea-water, amounted to ·0006, yet in contrast to analyses of sponges, repeated and careful tests with *Aurelia* and *Cyanea** failed to show the presence of that element. Another method showed its presence, but only ·00001 to ·00025 in 50 litres, and probably minute animals account for it. A very large quantity of the juice is necessary to determine its presence.† Does the gastro-vascular lining (i.e. the epithelial cells) reject iodides in sea-water, just as the sulphuric acid is rejected? If so, that is the explanation of the much smaller amount of iodine the medusa contains than the sea-water contains, in which it lives.

The conclusions yielded by the very elaborate and careful analyses of Professor Macallum, and summarised in the final pages of his paper, may be concisely stated as follows:—

1. Medusæ differ in their chemical composition, as regards salinity, from the sea-water in which they live, and two species differ from each other, in the same water and on the same day. Specific individuality is not signalized by morphological and anatomical features only, but is indicated by inorganic chemical composition as well.

2. The salinity of the sea-water environment may vary considerably, but affects very inconsiderably the salinity of organisms like medusæ.

3. Salts, once deposited in the jelly of living medusæ, are unaffected by osmosis while they continue to live in sea-water.

4. The sodium in medusæ is slightly less, and the potassium considerably more, than in the sea-water, taking the total halogen as the standard. The lime is about the same as in the sea-water, but the magnesia is less (as much as 10 per cent less), and the sulphuric acid very much less (32 to 35 per cent) in the medusæ.

5. The iron is more, and the iodine less, in medusæ than in sea-water; and the latter is apparently not associated with any compound which can be precipitated by alcohol.

6. The lining cells of the medusa's digestive system are living units, which exercise selection in absorbing the salts of sea-water, and this selection is more vigorous in respect to some constituents than others.

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* 2 litres of the juice were used.

†The total amount of proteid in *Aurelia* is very small, only 1/7 to 1/8 per cent of its total weight; thus 2,000 cc. of juice only yields a total of 2·6 grains of proteids.

7. The different selective preferences exercised are explained by the past history of the sea-water environment. Magnesia and sodium steadily increased, but lime and potassium must have reached their present proportions ages ago; and the internal epithelial cells of medusæ accommodated themselves accordingly, although they have not yet accommodated themselves to the increasing sodium and magnesia.

8. The inorganic composition of medusæ, as shown by Professor Macallum's researches, reflects the composition of sea-water less of to-day, than of past geological periods, possibly very remote periods.